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THE DISTRIBUTION OF ANCIENT VOLCANIC ROCKS ALONG THE EASTERN BORDER OF NORTH AMERICA.[1]

CONTENTS.

INTRODUCTION.
Diversity of Opinion regarding Ancient Volcanic Rocks.
- Great Britain.
- Germany.
- Belgium and France.
- Scandinavia.
- Russia.
- America.

Criteria for the recognition of Ancient Volcanic Rocks.
Distribution of Volcanic Areas in Eastern North America.
- Eastern Canada (Newfoundland, Cape Breton, Nova Scotia, Gaspé, New Brunswick, Eastern Townships).
- New England States (Maine, New Hampshire, Massachusetts).
- Middle Atlantic States (New York, Pennsylvania, Maryland, Virginia).
- Southern States (North Carolina, South Carolina, Georgia, Alabama).

General Conclusions.

THE great crystalline belt of the Eastern United States and Canada, in spite of all the attention it has received, is probably still the least understood geological province of our continent. Here, almost more than anywhere else, personal adherence to some preconceived theory of the origin and relationships of rocks has biased observation and led to contradictory or unsatisfactory

[1] This paper was outlined at the International Geological Congress in Chicago, August, 1893, and read in full before the Geological Society of America at its Boston Meeting, December 28, 1893.

interpretations of the facts. Only within recent years has detailed and independent work been undertaken in widely separated parts of this vast area, and as yet no sufficient data is at hand for structural, or even for petrographical correlation throughout the whole.

Complete geological maps, showing the structural relations and chronological sequence of all the crystalline formations, are undoubtedly what must be looked forward to as the ultimate aim of work within this region, but the most sanguine will surely admit that we are at present a long way from any such reality. Meanwhile, in the absence of paleontological evidence, the study of the rocks from the point of view of genesis and the establishment of petrographic correlations will do much toward furnishing the positive basis of knowledge upon which final solution of complex structure must rest.

Some of the notions regarding petrographic sequence and the origin of foliation, enforced by masters of geology high in authority, have obscured rather than advanced the problems presented by the crystalline rocks in eastern North America. Not only have we been taught that the mineralogical and structural characters of these rocks are safe indices of their superposition and relative age, but the interpretation of all parallel structures as proofs of sedimentation has led to the conclusion that igneous rocks are rare, if not altogether absent, in these oldest and generally foliated formations of the earth's crust. Now, however, better conceptions are beginning to prevail. No longer do we regard the petrographic character of a crystalline rock as any criterion of its age, while modern methods have enabled us to identify the abundant igneous rocks of ancient times in spite of the misleading structures imparted to them by secondary causes.

Object of this paper.—The present writer has had frequent occasion to insist on the presence of such disguised igneous masses in the oldest geological formations, and to dwell upon the methods by which their origin may be established. In the present paper it is his object to show that not only igneous, but

also *volcanic*[1] rocks are widely distributed through the crystalline belt of eastern North America, and to direct attention to them as offering a new and promising field for work in crystalline geology. For the accomplishment of this purpose it will be necessary (1) to consider the general attitude of geologists in different countries toward ancient volcanic rocks; (2) to specify the criteria available for their identification; and (3) to summarize our present knowledge of where such rocks certainly or probably exist in the eastern crystalline belt. The material embraced under the third of these heads has been obtained from personal work in the field, from a careful study of existing literature, and from unpublished observations and hints furnished by friends.[2]

It is hoped that the bringing together of what is now known of the distribution of ancient volcanic rocks in eastern North America, with the addition of new areas and indication of localities where they may be looked for, will stimulate further work in widely separated portions of this interesting field. These rocks have, it is true, already been correctly described at a few isolated points, but no attempt has before been made to connect such areas or to show their probably widespread distribution. The recent identification by the writer of a very extensive development of pre-Cambrian lavas and volcanic tuffs and breccias in the South Mountain of southern Pennsylvania and Maryland[3]

[1] The term *volcanic* might perhaps be applied with propriety to all rocks produced in or on a volcano, without regard to their structure or coarseness of grain. It is, however, here employed only for effusive or surface igneous rocks, in contrast to such as have solidified beneath the surface, either as the basal portions of volcanoes, or as dykes, sheets, laccolites, or stocks (bathylites).

[2] The writer is especially indebted for help to Professor Eugene Smith, of Alabama; Professor W. S. Bayley, of Waterville, Me.; Professor J. A. Holmes, of North Carolina; Professor H. D. Campbell, of Lexington, Va.; Dr. A. C. R. Selwyn, of Ottawa; Mr. L. V. Pirsson, of New Haven; Professor S. L. Powell, of Newberry, South Carolina, and Mr. Arthur Keith, of Washington. The "Azoic System" of Whitney and Wadsworth, and Professor Van Hise's Correlation Essay on the Algonkian have also proved of much service.

[3] Am. Jour. of Science (3d ser.), Vol. 44, p. 495, Dec., 1892. These rocks have been thoroughly studied by Miss Florence Bascom, whose results may be expected soon to appear in full and adequately illustrated form. See also this Journal, Vol. 1, No. 8, Dec., 1893.

naturally suggested a comparison of these rocks with those of similar character in the Boston basin and eastern Canada, as well as a further search for other regions of the same kind. This search has already proved successful in North Carolina and Maine, while an examination of the older literature indicates many other places where a recurrence of like conditions may be confidently expected.

The proper interpretation and areal mapping of all the demonstrably volcanic regions in the Appalachian crystallines will not only afford much material of interest in the study of petrography and dynamometamorphism, but will also contribute to the differentiation and final understanding of the vast belt of diverse crystalline rocks to which they belong.

DIVERSITY OF OPINION REGARDING ANCIENT VOLCANIC ROCKS.

There is notable in the different countries where geology is cultivated a wide diversity of opinion regarding ancient volcanic rocks. In some regions such rocks have been entirely overlooked or else misinterpreted; in others they are recognized, but are conceived as having been formed under circumstances so different from those which now obtain that they are genetically and inherently distinct from the products of modern volcanoes; in a few only are they considered as having been originally identical with recent effusive rocks, and as differing from them only in alterations due to subsequent causes. This diversity of opinion may be accounted for in part by the varying state of preservation of ancient volcanic material in different parts of the earth's surface or by the lack of experience of field geologists with the characteristic features of modern lavas. It is, however, also due in a measure to the persistence of certain ideas promulgated by early masters of the science in their respective lands.

It was in Great Britain that the real nature of ancient volcanic products received its earliest and fullest recognition. In spite of the absence of active volcanoes from the islands, these rocks have from the earliest days of geological inquiry been favorite

subjects of investigation. From the first, their essential identity with modern volcanic products has been clearly recognized and repeatedly insisted upon—something which we may attribute to the doctrines of Hutton and to the uniformitarian principles of Lyell. Such geologists as Scrope, de la Beche, Sedgwick, Murchison, Jukes, Lyell and Ramsay, speak continually of lava-flows, tuffs, breccias and ash-beds in a way that implies no doubt in their minds as to the existence of volcanoes like those now active, in Paleozoic and pre-Paleozoic times. And more recently the delicate methods of modern petrography have in the same country been first made to establish the identity between ancient volcanic rocks and those of the present. The world is now but beginning to follow in this respect the lead set by Allport, J. A. Phillips, Judd, Bonney, Rutley, Harker, Cole and others in Great Britain. A few Englishmen, like Mallet or Hicks, have considered the oldest volcanic rocks either as originally different from those now produced, or as characteristic of some definite geological horizon, but, on the whole, the British school of geology, more than any other, recognizes a practical uniformity in the nature of volcanic action and products from the Archean to the present.[1]

In Germany and France volcanic rocks (*Ergussgesteine*) are recognized as abundant in certain of the earlier geological formations. Nevertheless there is in these countries a prevailing tendency to separate Tertiary from pre-Tertiary rocks of this class as things originally and genetically distinct.[2] It is noticeable that the earlier schemes of rock-classification, like those of Brongniart, Haüy, Cordier and K. C. von Leonhard, are quite purely mineralogical. The division of older and younger, or paleo- and neo-volcanic rocks is to be in part accounted for by the concentration of these masses in central Europe within the Permo-Carboniferous and Tertiary periods and their comparative

[1] See "The History of Volcanic Action in the Area of the British Isles," Presidential Address by Sir ARCHIBALD GEIKIE, F.R.S., etc. Quart. Jour. Geol. Soc., Vols. 47 and 48, 1891–2.

[2] ROTH: Sitzber. Berl. Ak. 1869, p. 72, *et seq.* ZIRKEL: Lehrbuch der Petrographie, 2d. ed., Vol. I., p. 838, 1893.

rarity in Mesozoic times. It is, however, also connected with the Wernerian doctrine of the non-recurrence of certain physical conditions in the earth's development, as contrasted with the uniformitarianism of Hutton and Lyell. The absence of volcanic types in Europe which serve to bridge over the sharp contrast between those of the Carboniferous and Tertiary, is being rapidly compensated by the discovery of such rocks in other regions. Fortunate finds of even pre-Cambrian lavas so perfectly preserved as to demonstrate their practical identity, both chemically and structurally, with recent products is tending to weaken the old distinction on the continent. There are now many signs of progress toward the idea that the characters regarded as belonging peculiarly to the older effusive rocks are better explained through changes subsequent to their solidification.

Thus Ludwig in 1861,[1] Vogelsang in 1867,[2] and Lossen in 1869,[3] regard some quartz-porphyries as only devitrified glasses, identical with those of modern volcanic regions; Kalkowsky,[4] and recently Sauer[5] and Vogel,[6] have also brought convincing proof that such is often the case.

Gümbel says: "Es scheint in dieser Beziehung denn doch eher gerechtfertigt, zunächst das petrographisch Gleiche auch gleich zu bezeichnen, als in einzelnen Fällen ein neues Princip, das *des Alters*, in die Petrographie einzuführen, welches bei den meisten übrigen Fällen nicht verglichen und berücksicht werden kann;"[7]

And Rosenbusch also remarks:

"Man hat *den geologischen Alter* der Eruptivgesteine bisher ein höheres bestimmendes Moment für die structurelle und mineralogische Ausbildung dieser zugeschrieben als demselben in Wirklichkeit zukommt."[8]

[1] Erl. z. geol. Karte Hessens, Bl. Dieburg, p. 56, 1861.

[2] Philosophie der Geologie, pp. 144–146, 1867.

[3] Abh. Berl. Ak., 1869, p. 85.

[4] TSCHERMAK'S Min. Mitth, pp. 31 and 58, 1874.

[5] Erl. zur geol. Specialkarte Sachsens, Bl. Meissen, pp. 81–91, 1889

[6] Abh. geol. Landesanstalt von Hessen, vol. ii., p. 38, 1892.

[7] Grundzüge der Geologie, 1888, p. 85.

[8] Die massigen Gesteine, 2d. ed., 1887, p. 4.

He nevertheless adheres to the division between paleo- and neo-volcanic rocks, although he says that about their only difference is that the latter can often be found to belong to volcanoes (*i. e.*, volcanic mountains) which are themselves so extremely subject to removal by erosion.[1]

Admirable observations on the use of age in rock-classification are made by M. Neumayr. He says:

"Wohl muss der Geolog dem Alter der Gesteine Rechnung tragen, aber diese Berücksichtigung ist eine von der Beschreibung und Eintheilung der Gesteine durchaus unabhängige Sache. Wie schon oft betont worden ist, ist unter den Sedimentärgesteinen das richtige Prinzip schon durchgeführt, dass man von Kalken, von Dolomiten, Sandsteinen, etc., des Silur, des Jura, des Tertiär spricht, ohne die verschiedenalterigen Gesteine von gleicher Beschaffenheit mit eignen Namen zu belegen; genau in derselben Weise wird man auch mit den Massengesteinen verfahren müssen. Auf einen solchen Standpunkt wird und muss die Gesteinslehre ebenfalls gelangen; sie wird ihre Unterscheidung der Felsarten nur nach petrographischen Merkmalen und petrographischer Methode vornehmen, und die Altersbestimmung der Geologie überlassen, was natürlich nicht ausschliesst, dass beide Forschungsgebiete von einer und derselben Person beherrscht werden."[2]

In Belgium we see de la Vallée Poussin in 1885 writing of "Les anciennes Rhyolites dites Eurites,"[3] just as they would in England; while in France the recognized leader in petrographical usage, Michel-Lévy, although he still distinguishes "*roches porphyriques ante-tertiaires*," from "*roches trachytoides tertiaires et post-tertiaires*," expresses himself in regard to the futility of the age distinction in rock nomenclature as follows:

"On voit, par tout ce qui précède, qu'il est nécessaire d'asseoir une classification pétrographique rationnelle sur des faits contingents, indépendents d'hypothèses géogénétiques, et que la considération de l'âge des roches, à ce point de vue, est aussi hypothétique que celle de leurs conditions de gisement dans les profondeurs ou à la surface. Etant donné un échantillon de provenance inconnue, il est indispensible et il est possible de le nommer et de le décrire sans amphibologie. Il n'est possible d'en déterminer, avec certitude et précision ni le gisement ni l'âge géologique."[4]

[1] Ib., p. 6.

[2] Erdgeschichte, Vol. 1, p. 599.

[3] Bull. de l'Acad. roy. de Belgique (3) Vol. 10, No. 8, 1885.

[4] Structures et Classification des Roches Eruptives, p. 34, 1889.

In Scandinavia, if we judge from the most recent publications, there is, in spite of the general adherence to German nomenclature, a fuller recognition of the similarity between ancient and modern volcanic rocks than is to be found in any other part of Europe except England.

On the western coast of Norway, Reusch describes old lava flows of quartz-porphyry and more basic diabase amygdaloids which show spheroidal parting on a large scale due to cooling. These rocks are accompanied by tuffs and breccias which, in spite of subsequent dynamic action, still show their original characters. In one case, on the island of Gjeitung, occurs a deposit of pumice bombs cemented by what is now a chlorite schist.[1]

In Sweden Högbom describes the general distribution of post-Archean (Algonkian) eruptive rocks, many of which bear unmistakable evidence of volcanic character.[2] Otto Nordenskjold assigns the beautiful flow-porphyries and amygdaloids of the Elfdalen region to the same horizon, while he concludes that most of the Hälleflintas of southeastern Sweden (Småland) are surface lavas. He finds in them such well-developed fluidal, eutaxitic, rhyolitic and perlitic structures that they may be regarded as old rhyolites or devitrified obsidians.[3] The probably much younger and still glassy rhyolites of the gneiss area of Lake Mien are described by N. O. Holst.[4]

In Russia Tschernyschew describes from the central Urals many types of eruptive rocks, and among them both acid and basic volcanics of great antiquity, accompanied by their agglomerates, breccias and tuffs.[5]

In America the recognition of the true character and relationships of ancient volcanic rocks has been greatly retarded both

[1] Bömmelöen og Karmöen, pp. 109, 122, and 403, 1888.

[2] Geologiska Fören. i Stock. Förh., Vol. 15, p. 209, 1893.

[3] Bull. geol. Soc. Upsala, Vol. 1, Nos. 1 and 2, 1893.

[4] Afhandl. Sverig. geol. Undersök. Ser. C, No. 110, 1890.

[5] Allgemeine geologische Karte von Russland, Bl. 139, Central Urals. Text 4° pp. 323 and 333, 1889.

by the adherents to the so-called metamorphic school, like Dana, Logan, Rogers, Lesley and Winchell, who fail to find among the ancient foliated crystallines anything beside altered sediments, but perhaps even more by the influence of that most extreme of all Wernerians, Dr. T. Sterry Hunt. While antithetically opposed to the members of the metamorphic school in his notions of lithological character as an index of geological position, Dr. Hunt had in common with them the conviction that the ancient lavas and volcanic breccias, tuffs and ash-beds were normal aqueous deposits. The basic volcanics of eastern North America enter so argely into his "Huronian," and the acid types so largely into his "Arvonian," that his writings may still be used as suggestive of localities where ancient effusive rocks may be sought for.[1]

But there have not been wanting those among the earlier American geologists who have clearly recognized the igneous members of the ancient crystalline formations, in spite of their disguised character. Prominent among them are E. Hitchcock, Emmons, Lieber, Foster and Whitney. Not only the igneous, but the volcanic (surface) character of the Lake Superior lavas has been maintained by Pumpelly,[2] Wadsworth,[3] Irving,[4] Van Hise[5] and the present writer.[6] In Canada igneous rocks have always been regarded abundant in the oldest formations, while the volcanic character of some of them has been insisted on by Selwyn[7] and mentioned by other members of the Canadian Geological Survey. A looseness of usage is, however, observable in some of these reports, where "volcanic" is made synonymous

[1] See: Presidential Address, Am. Assn. Adv. Sci., 1871; Proc. Am. Assn. Adv. Sci., 1876, p. 211–211; Azoic Rocks, 1878; Am. Jour. Science, May, 1880; Mineral Physiology and Physiography, Chap. IX., 1886.

[2] Geology of Michigan, Vol. 1, 1873.

[3] Bull. Mus. Comp. Zoöl., Vol. 7, p. 111, 1880.

[4] Monograph V., U. S. Geological Survey, 1883.

[5] Bull. Geol. Soc. Am., Vol. 4, p. 435, 1893.

[6] Bull. U. S. Geol. Surv., No. 62, p. 192, *et seq.*, 1890.

[7] Report of the Geol. Survey of Canada for 1877–78. A, p. 5. Trans. Roy. Soc. of Canada, Vol. 1, p. 10, 1882.

with "igneous."[1] In the eastern United States Wadsworth was the first to declare for the volcanic origin of the felsites and tuffs in the Boston basin which, through the influence of Hunt's doctrine had, after Hitchcock's time, come to be explained as sediments. To Dr. Wadsworth also belongs the honor of having been the first geologist on this continent to insist on the original identity of these old lavas and pyroclastics with the recent volcanic rocks of the Cordilleras.[2] There is little doubt that the finely preserved ancient volcanic material in the eastern crystalline belt and elsewhere will, when it is adequately studied, finally bring to this opinion most American geologists. If we as yet know little of the extent and distribution of our ancient volcanics, we are at least bound by no traditions to artificial and useless age distinctions, and may freely follow the lead of our English colleagues.

CRITERIA FOR THE RECOGNITION OF ANCIENT VOLCANIC ROCKS.

It is a self-evident proposition that the identification of certain rocks as volcanic products is in no way dependent upon their present association with a recognizable crater or volcanic mountain. By volcanic rocks we understand igneous or pyroclastic material which has solidified or been deposited at, or very near the earth's surface. It is of little moment whether or not it was ever piled into conical mountains. That the rocks themselves bear witness to their origin and conditions of formation is sufficient. The successive effects of erosion on the easily removed volcanic mountains has been so often graphically described[3] that no further reference to the subject is here necessary. If the Eocene or Triassic volcanoes have so disappeared as to leave

[1] For instance, Ells in his "Geology of the Eastern Townships" (Can. Rept. for 1886, J.) speaks of pre-Cambrian rocks as "volcanic" and "plutonic," but enumerates only granite, diorite and serpentine.

[2] Bull. Mus. Comp. Zoöl., Vol. 5, 1879, p. 277 *et seq.*, and Azoic System, ib., Vol. 7, 1884, p. 429.

[3] See, DE LA BECHE: Geological Observer, pp. 526–537, 1851. M. NEUMAYR: Erdgeschichte, Vol. 1, pp. 202–204, 1887. W. M. DAVIS: "The Lost Volcanoes of Connecticut," Popular Science Monthly, Dec., 1891.

only traces of their original forms, what may we expect of those of Paleozoic or Archean times?

On the other hand, the association in dissected volcanic regions of the effusive rocks with correspondingly abyssal types naturally *suggests* that volcanoes may have once surmounted many areas of coarsely granular ancient igneous rocks. As this, however, cannot be proved, only such regions are here considered as yield rocks of unmistakably surface origin.

Again, ancient volcanic rocks may have been subjected to metamorphosing processes severe enough to have destroyed most of their original characters. In such cases, patient study and a careful weighing of all evidence is necessary to decide their origin, and even that may not avail. Igneous rocks may be so altered as to be indistinguishable from metamorphosed sediments, but it many cases where this at first appears to be the fact, some decisive clue may be discovered.

In establishing the volcanic nature of rocks occurring in ancient and more or less crystalline terrains, attention must be given to several different sets of characters. The field relations must be carefully studied and the material collected on the spot and afterward studied in the laboratory. The criteria for deciding on their igneous and volcanic origin may be arranged as follows:

I. If the rocks are *igneous*, whether abyssal or surface, they will:
   1. Conform in chemical composition to certain well established types;
   2. Show an association of petrographical types which, both chemically and mineralogically, follow the laws of consanguinity.

II. If they are *volcanic*:
   1. They may be found in the field to occur in distinct sheets, flows or necks;
   2. They will have produced very little or no contact action in the adjoining rocks;
   3. They may include irregular fragments of other rocks.

III. If they are *volcanic:*

1. They may appear to be striped, banded, or pseudo-"stratified" conformably to adjoining sedimentary deposits;
2. They will probably be accompanied by fragmental (pyroclastic) material, which may or may not itself be really stratified. Such material will vary greatly in coarseness, containing bombs, agglomerates, breccias, tuffs, sands and ashes. The characteristics of these are:
   1) indiscriminate mixture of all sizes and shapes of fragments;
   2) material of same kind as the igneous rocks;
   3) cement, either finer fragmental material (tuff-breccia) or lava (flow-breccia);
   4) very angular shape of smallest fragments (microscopic glass sherds).
   5) if ancient volcanoes were on the shore-line, such material may have been immediately worked over by water and interbedded with more or less normal aqueous sediments.

IV. Most important of all, however, is the identification of those characteristic structures known to originate only in glassy, half-glassy or very fine grained porphyritic rocks, solidifying at the surface, or in very narrow dykes where solidification has been rapid. These will be found to be very persistent and can usually be identified under the microscope in spite of devitrification, alteration, or even a considerable degree of dynamometamorphism. The most common of these structures are:

1. a vesicular, scoriaceous, pumiceous or amygdaloidal structure;
2. a sharply defined, small porphyritic structure with a glassy, half-glassy or felsitic (cryptocrystalline) base;
3. a spherulitic structure, due to either large or small lithopysæ, hollow spherulites, or compact spherulites,

arranged either irregularly, or in more or less discontinuous bands or layers;

4. a flow structure, produced either by the elongation of vesicles or the parallel arrangement of constituents or crystallites. It may also be produced by the interlacing of different colored magmas (eutaxitic structure);
5. corroded phenocrysts, quartz with embayments, or skeleton crystals due to rapid and imperfect growth;
6. microscopic spherulites, globulites, trichites, crystallites, real or devitrified glass inclusions, quartz with orientated siliceous aureoles, axiolites, etc.;
7. perlitic structure, wholly or partly devitrified.

Although some of these structures may occasionally occur in dykes or other igneous rocks which have rapidly solidified beneath the surface, they are nevertheless so essentially characteristic of effusive lavas, that, in lack of any evidence to the contrary, they may be regarded as fairly safe guides in establishing the effusive nature of rocks. This evidence is beyond doubt, if such rocks are accompanied, as they generally are, by ash material.

While a single one of these characteristics may not be sufficient to identify a volcanic occurrence, many, if not all of them, will be found to occur together, and only in rare instances will it be found that some of them, at least, have not survived the vicissitudes of metamorphism. That many regions in the ancient crystalline belt of the Appalachian system exhibit most of them in great perfection is now well known. It is only a misinterpretation of these characteristic features of volcanic rocks, due to a lack of acquaintance on the part of observers with their recent analogues, that has prevented their recognition long ago. Thus, by those who have heretofore described these rocks as sediments, both secondary cleavage, and the banding due to flow or parallel spherulitic layers have been mistaken for stratification; spherulites have been erroneously regarded as concretions; and the accompanying pyroclastics, as normal conglomerates or slates.

It is the purpose of the writer in the present paper to maintain that *in the great crystalline belt of eastern North America, large areas of volcanic rocks occur, and that these, in spite of their great age, are in all respects the same as modern volcanic materials, save for alterations subsequent to their original formation—among which alterations devitrification has been one of the most important.*[1]

DISTRIBUTION OF VOLCANIC AREAS ALONG EASTERN NORTH AMERICA.

I shall now proceed to summarize the present state of our knowledge of these volcanic areas, as far as they belong to the Eastern or Appalachian crystalline belt, omitting all reference to the central Canadian, Lake Superior, Missouri, or other more western regions of similar nature. In this review I shall commence with Newfoundland and follow them southwest, parallel to the coast.

Eastern Canada.—In a recent comparison between the Eozoic and Paleozoic rocks of eastern America and western Europe, Sir William Dawson says that the Huronian was evidently a coarse marginal deposit, accompanied by abundant volcanic outbreaks, similar to those which occurred about the same time in Wales. He is also confident that many of the bedded Huronian rocks are really of volcanic origin, being ashes in an altered state.[2] In the same paper he mentions volcanic rocks, both lavas and pyroclastics, as abundant in the Ordivician and Silurian formations of eastern Canada.

The reports of the Canadian and Newfoundland surveys abound in references to rocks of a volcanic character in the early Paleozoic and pre-Paleozoic horizons. These references are, however, always purely those of a field-geologist engaged in a rapid reconnaissance. The frequent use of such field terms as felsite, porphyry, trap, amygdaloid, agglomerate, breccia and ash suggest a vast development of contemporaneous volcanic

[1] On the nomenclature of these ancient and devitrified lavas, see Miss FLORENCE BASCOM'S paper, this Journal, Vol. I., No. 8, p. 825, Nov.–Dec. 1893.

[2] Quart. Jour. Geol. Soc., Vol. 44, p. 801, 1888.

materials, but thus far no petrographer has attempted to study systematically either the field or microscopical relations of any area of these interesting rocks. A very broad and interesting field is thus seen to be awaiting investigation in Newfoundland, Gaspé, New Brunswick, Nova Scotia and the Eastern Townships.

Professor J. B. Jukes, in his "Geology of Newfoundland," describes old lava flows and accompanying pyroclastic deposits as very abundant, especially on the peninsula of Avalon, which forms the eastern part of the island.[1] His observations are confirmed by the later reports of Murray and Howley, who agree that the western part of this peninsula was the scene of extraordinary volcanic activity in very early times.[2]

In his three reports on the eastern portion of Cape Breton, Fletcher describes the Ste. Anne, Boisdale, Coxheath, East Bay and Mira Hills, as composed largely of ancient (pre-Cambrian) volcanic rocks, among which felsites of all colors, felsite-porphyries, felsite breccias and amygdaloids abound.[3] Similar rocks appear also to extend up into, and to form an important part of the Cambrian, Silurian and Devonian formations. In a later report on the northern part of Cape Breton, Fletcher[4] finds that the greater part of the northern peninsula is also composed of "felsites," but the petrographical distinctions of both Fletcher and Gilpin[5] are so indefinite that a variety of coarsely crystalline rocks seem to be embraced in this general designation. In describing the Mira "felsites," Fletcher mentions those of Blue Mountain and Gull Cape, near Louisburg, as being "globular," or "concretionary," (coarsely spherulitic?) often presenting "single or united spheroids, the concentric layers of which may

[1] Excursions in and about Newfoundland in 1839 and 1840, 2 vols., 1843. Geology, Vol. 2, pp. 245–341.

[2] Reports of the Geological Survey of Newfoundland for 1868–1881.

[3] Reports of the Geol. Survey of Canada, 1875–76, pp. 369–418; ib., 1876–77, pp. 402–456; ib. 1877–78, pp. 1–32, F.

[4] Ib., 1882–83–84, pp. 1–98 H.

[5] Quart. Jour. Geol. Soc., Vol. 42, p. 515, 1886.

be removed like the coats of an onion." He also speaks of them as "coarsely brecciated" and "vesicular." A point of some interest is Fletcher's conclusion that "both felsite and syenitic strata are intimately associated as part of the same group of crystalline rocks, differing, not so much in composition as in the degree of crystallization they have been subjected to" (*sic*).[1] In greatly eroded regions we should expect to find surface volcanic rocks associated with their coarser abyssal equivalents.

In Nova Scotia proper the best known area of ancient volcanic rocks is in the northeastern corner of the province, near Arisaig, in Antigonish county. These were considered by Sir William Dawson in 1850 as "metamorphic."[2] In 1864, Dr. Honeyman described them as vesicular traps, amygdaloids and porphyries, associated with tufa and tufaceous conglomerate.[3] In his first report on eastern Nova Scotia, Fletcher describes variegated, vesicular and amygdaloidal "felsites" and "fragmentary felsites," like those of Coxheath and Louisburg, associated with "syenite" (hornblende granite) and diorite.[4] These rocks are regarded as pre-Cambrian, and are particularly developed at Arichat, Cape Porcupine on the Straits of Canso, and in the Sporting, North and Craignish mountains. In the North Mountains the felsites are said to pass gradually into syenite (l. c. p. 14). The gradual blending of the felsite and overlying George River limestone is attributed to "common metamorphism," rather than "to contemporaneous volcanic origin or subsequent intrusion" (l. c. p. 17). Nevertheless, at Cape Porcupine the felsite is regarded as possibly an igneous rock, since "the apparent lines of bedding are like those of a furnace slag" (l. c. p. 25). In the subsequent report of the extension of his explorations southward and westward in Nova Scotia, Fletcher admits the volcanic origin of the felsitic rocks of Arisaig, Doc-

[1] Quoted by GILPIN: Quart. Jour. Geol. Soc., Vol. 42, p. 516.

[2] Quart. Jour. Geol. Soc., Vol. 6, p. 347, 1850.

[3] Ib., Vol. 20, p. 333, 1864.

[4] Report of the Geol. Survey of Canada, 1879–80, F.

tor's Brook, Georgeville, Blue Mountain and East River of St. Mary's. These are quite like the Cape Breton and Cape Porcupine rocks, and carry copper, as they do in South Mountain, Pa., and on Lake Superior. He gives the age of these eruptions as probably pre-Cambrian, although at Arisaig they may be of any age older than Medina. Similar volcanic eruptions occur in all strata up to the base of the Carboniferous.[1] In his last report covering Pictou and Colchester counties, the same author describes Cambro-Silurian porphyries, agglomerates, fragmental felsites, breccias and amygdaloids from Moose and Sutherland rivers. A dyke-like mass of volcanic breccia occurs on Sam Cameron's brook. Similar volcanic products are also very apparent in the Devonian of these two counties, among the most interesting of which are the syenitic granites overlaid by thick volcanic deposits at the east end of the Cobequid Hills, as described by Dawson.[2] The well-known traps of northwestern Nova Scotia, along the Bay of Fundy, which furnish the beautiful zeolites and other minerals, are of Triassic age.

In New Brunswick and the Gaspé Peninsula, old volcanic rocks, like those of Newfoundland and Nova Scotia, are extensively developed. Ells and Low mention amygdaloidal traps and porphyries cutting various strata of Gaspé, up to and including the Devonian.[3] Felsitic rocks, similar to those which are better known further to the south, are rather vaguely mentioned by Robb in northern New Brunswick.[4] Ells, in his report on the same region in 1879–80, clearly describes as volcanic both acid and basic rocks. A vast area of felsite, petrosilex, porphyry and breccia, like that near St. Johns, is developed in the upper Nipisiguet river and lake Nictor. Another like it extends from the upper Upsalquitch river along Jacket river to the bay of Chaleur, while great masses of basic volcanics (amyg-

[1] Ib., 1886, P.

[2] Acadian Geology, 1878, suppl., p. 79.
Report of the Geol. Survey of Canada, new ser., Vol. 5, 1890–91, P. pp. 147–166.

[3] Ib., 1882–83–84, E. and F.

[4] Ib., 1870–71, p. 245.

daloids, aphanites, etc.) occur around the head of the Bay of Chaleur and Dalhousie, as well as on the upper Upsalquitch and Elm Tree rivers. Many of these rocks are pre-Cambrian, while others cut the Silurian strata.[1] Great sheets of contemporaneous trap are also found by Ells in the Silurian, and to a very small extent in the Devonian, along the north shore of the Bay of Chaleur. Bailey explored parts of northern and western New Brunswick, especially in Carolton, York and Victoria counties, and found porphyries, felsites and amygdaloids, intrusive in the Silurian and older formations in Canterbury, Woodstock and Kent townships, near the St. Johns river.[2] Still later Bailey and McInnes continued similar explorations, and found signs of intense volcanic action in the Niagara limestone at Pointe aux Trembles, and a great development of acid and basic surface rocks near the Aroostook river and at Presqu'ile and Haystack mountain in Maine.[3] The same is true near Tobique lake, farther to the northeast.

As early as 1839, Gesner describes the volcanic rocks along the Bay of Fundy, in southern New Brunswick, as belonging to several distinct horizons.[4] In 1865, Bailey, Matthew and Hartt distinguished two groups mainly of volcanic origin, to one of which, the "Coldbrook," they assigned a Huronian, and to the other, the "Bloomsbury," a Devonian age.[5] In 1872, Bailey and Matthew, after a season's field-work with Dr. T. Sterry Hunt, united the Coldbrook and Bloomsbury groups on purely lithological grounds, and for the same reason joined with them two other volcanic series—the Coastal and Kingston groups—exposed at other localities in southern New Brunswick.[6] The petrographical characters of these rocks were those regarded by Hunt as sufficient demonstration of Huronian age. The acceptance of this fallacious principle exercised a distinctly

[1] Ib., 1879–80, pp. 35 to 42.

[2] Ib., 2882–83–84, G. pp. 15 and 20; ib., 1885, G. pp. 22 and 28.

[3] Ib., 1886, N. pp. 14–15; and ib., 1887–88, M. pp. 32 and 47.

[4] First Report on the Geological Survey of the Province of New Brunswick, by ABRAHAM GESNER. 87 pp. 1839.

[5] Observations on the Geology of Southern New Brunswick. 1865.

[6] Report of the Geol. Survey of Canada, 1870–71, pp. 57–133.

retarding effect on the deciphering of New Brunswick geology. Numerous occurrences of felsite, porphyries and amygdaloids were described between Musquosh Harbor and Loch Lomond, near the city of St. Johns, and along the line between Kings and Queens counties (Coldbrook and Bloomsbury groups). Similar rocks were traced from L'Etang Harbor, near Passamaquoddy Bay, along the edge of the Bay of Fundy to Shepody, in Albert County (Coastal group); and finally, a belt of analogous composition was described between the Long Reach of the St. Johns river and Mace's bay (Kingston group). These rocks were at this time, however, on account of Hunt's influence, united with their associated sediments, and nothing is said about their volcanic character. These authors were forced to regard similar rocks on the shores of Passamaquoddy bay as Silurian, because of associated fossils, in spite of their lithological identity with the "Huronian." These they called the Mascarene series.[1]

Four years later the same authors united the Kingston and Mascarene groups and regarded both as upper Silurian.[2] In a report of the pre-Silurian rocks of Albert, eastern Kings, and St. Johns counties, Ells gives some clear statements relative to the volcanic rocks of southern New Brunswick. He says:

"In their lithological aspect, the rocks forming the southern metamorphic belt present great diversity. Their general character is of two kinds—altered sedimentary and volcanic. * * * In the latter we include the great mass of petrosiliceous rocks, so called, with breccias and other ash rocks, which in places show bedding, but this is often so obscurely marked as to be exceedingly doubtful. * * * Near the contact of the volcanic and sedimentary rocks we find an extraordinary development of generally coarsely crystalline diorites and syenites, which would seem to form the basal portion of the volcanic part of the series."[3]

A report on the same rocks was published at the same time by Bailey, who divides them into a feldspathic, syenetic and gneissic group, including limestones, serpentines, and dolomites

[1] Ib., pp. 144–158.

[2] Ib., 1874–75, pp. 85–89.

[3] Ib., 1877–78, D. p. 3.

(Laurentian); a felsite-petrosilex group (Lower Huronian or Coldbrook); and a schistose, chloritic micaceous group (Upper Huronian or Coastal).[1] The results of all their work on the rocks of southern New Brunswick is summarized by Bailey, Matthew and Ells, with a general geological map in three sheets.[2]

That portion of the Province of Quebec lying south and east of the St. Lawrence is called the Eastern Townships. We have already considered that portion of it composing the Gaspé peninsula. The portion lying west of Maine and north of New Hampshire and Vermont was supposed by Logan to be wholly occupied by rocks of the Quebec Group. In 1879, Dr. Selwyn divided the rocks of this zone into three groups, which he defined as lower Silurian; volcanic (probably lower Cambrian); and crystalline (probably Huronian). The lower of these divisions forms an anticlinal axis extending from Lake Memphremagog to L'Islet County, 150 miles. It contains a great variety of altered sedimentary beds, associated with "diorites, dolerites, serpentines, amygdaloids, and volcanic agglomerates," regarded by Hunt as altered sedimentaries. The second division, said to be intimately related to the last, is largely composed

"especially on the southeastern side of the axis, of altered volcanic products both intrusive and interstratified, the latter being clearly of contemporaneous origin with the associated sandstones and slates."

These rocks are designated as

"dioritic, epidotic, and serpentinous breccias and agglomerates; diorites, dolerites and amygdaloids holding copper ore; serpentines, felsites and some fine grained granitic and gneissic rocks."

They are especially developed along the contact of the last-mentioned group, of which they "may be merely the upward extension."[3] In a later paper on the Quebec Group, Dr. Selwyn considers these volcanic rocks thoroughly from the English point of view. He says:

[1] Ib., DD. p. 2.

[2] Ib., 1878–79, D. p. 26.

[3] Ib., 1877–78, A. pp. 5–9.

"I would also submit that neither a schistose nor a bedded structure can be accepted as proof of a non-igneous or volcanic origin, and that a once massive lava-flow, whether augitic or feldspathic, is as likely, through pressure and metamorphism, to assume a schistose structure as are ordinary sedimentary strata. It is, I am aware, not in accordance with generally received ideas on the nature of ancient igneous rocks to suppose they can be schistose and stratified, especially so in America, where volcanic agency in the earlier geological periods has been almost entirely ignored, and all those rocks which by their microscopic characters and chemical composition, and by their geological associations and relations, point to volcanic agency as the cause of their formation, have been said to be '*not igneous, but metamorphic in origin*,' a description which, it seems to me, is decidedly self-contradictory."[1]

Selwyn later again maintained his volcanic group, and published microscopic descriptions of some of its rocks (quartz-porphyry and porphyrite) by Adams.[2] Little or nothing is added to our knowledge of the strictly volcanic rocks by the two subsequent reports on the geology of the Eastern Townships by Ells.[3]

The recognition of ancient volcanic rocks in the United States is far behind that which prevails in Canada. This, as has already been pointed out, is due to the influence of so-called "metamorphic" ideas, or more properly to the Wernerian doctrine, that every rock showing any foliated or parallel structure is sedimentary.

New England.—Very little definite information can be gathered from the earlier reports on the geology of Maine, by Jackson and C. H. Hitchcock, regarding the old volcanic deposits. Jackson frequently uses such petrographical terms as "amygdaloidal trap, ribbon jasper, clinkstone porphyry, and breccia composed of an infinity of fragments of jasper," in describing the rocks near Eastport and Machiasport, on the Maine coast. He regarded the basic rocks (trap) as eruptive, but the "jasper" as semifused sediments whose lines of stratification were still pre-

[1] Trans. Roy. Soc. Canada, Vol. 1, p. 10, 1882.

[2] Report of the Geol. Survey of Canada, 1880–82, A. p. 2 and pp. 10–14.

[3] Ib., 1886, J., and ib., 1887–88, K.

served.[1] His descriptions are, however, very suggestive, especially in light of the truly volcanic rocks which have been recently discovered in the older strata of Maine. C. H. Hitchcock, in his Maine reports, regards the acid volcanic rocks near Machiasport as altered slates, and mentions extensive areas of similar rocks on Moosehead, Portage, Long, and Chamberlain lakes, as well as along the Aroostook and Penobscot rivers, in the interior of the state.[2] Goodale gives four patches of analogous "siliceous slates" in York county, and five in Oxford county, and J. H. Huntington describes the summit of the diorite southeast of Kennebago lake, in western Maine, as composed of compact felsite, which he regards as an eruptive rock.[3] The first definite descriptions of ancient volcanic rocks in Maine was given by Professor Shaler, who examined the regions about Eastport and Mount Desert. Near Eastport, and especially on McMaster's island, three types of volcanic material are largely developed: 1) detrital accumulations which have fallen through the air; 2) true lava flows; 3) dykes. They seem to belong to various horizons of Silurian age.[4] A similar series of interstratified volcanic breccias, lava flows and ash beds are described as forming a large part of Mt. Desert island south of Southwest Harbor, and the Cranberry Isles.[5]

The writer has had the opportunity to personally examine the volcanic rocks of the Mt. Desert region, and he is indebted to Professor W. S. Bayley of Waterville, Me., for specimens and slides of the beautiful lavas of Vinal Haven, and to Mr. E. B. Mathews for notes and specimens of similar rocks from Mt. Kineo on Moosehead Lake.

Along the shores of Cranberry Island occur hard jaspery felsites, often porphyritic, and exhibiting such characteristic features of glassy rocks as spherulites, single and in bands, flow-

[1] First Report on the Geology of the State of Maine, 1837, p. 12 and pp. 36–42.

[2] Geological Report, 1861, p. 190, and p. 432; also ib., 1863. p. 330.

[3] Proc. Am. Assn. Adv. Sci., Vol. 26, p. 286, 1877.

[4] Am. Jour. of Science (3d ser.), Vol. 32, pp. 40–43, 1886.

[5] Eighth Ann. Report U. S. Geol. Survey, pp. 1037, 1043, 1054. 1889.

structure, etc., in great perfection, although all trace of the original glass has long since disappeared. The rocks collected by Professor Bayley on the north side of Vinal Haven and on the opposite shore west of North Haven are, according to his field observations, all surface flows or tuffs. Of the nine specimens kindly submitted to me for examination by Professor Bayley, one is a medium grained microgranite and all the others

FIG. 1.

FIG. 1. Devitrified glass-breccia from north side of Vinal Haven, Penobscot Bay, Me. Magnified six times.

are devitrified glassy rocks, which were once either obsidians, glass breccias, or tuffs. No. 94 is a banded flow-felsite, a devitrified glass with narrow chains of spherulites. No. 100 is a devitrified obsidian containing delicate flow-lines produced by trichites, some zircon crystals, and spherulitic bands in which epidote has been secondarily produced. No. 126 is a pale gray felsite containing large round nodules which may be spherulites. Under the microscope it shows a pronounced perlitic structure. These rocks contain spherulitic structures which are not devitrification products but original, if we may judge from their absolute identity with similar structures in the glassy rocks from Obsidian Cliff. The other five specimens are fine grained vol-

canic ashes, most of them composed of very sharply angular fragments of devitrified glass or pumice with beautiful flow structures. The delicate detail produced by trichites in one of these is rather roughly represented in Fig. 1. It is not unlike the devitrified glass-breccia described by the writer from Onaping river in the Sudbury district.[1]

The specimens collected by Mr. Mathews at Mount Kineo on Moosehead Lake, and kindly loaned me for examination, are typical quartz-porphyries or keratophyres, some of which exhibit such perfect and delicate flow-lines that they can be regarded only as devitrified glassy lavas.

In New Hampshire felsites and quartz-porphyries abound. They were regarded as eruptive by Hitchcock and by Hawes when they occur in dykes, although the latter regarded many of them, especially when interstratified, as sediments fused *in situ*.[2] There are as yet no published descriptions which make it reasonably certain that truly volcanic, as contrasted with abyssal igneous rocks, occur within this state.

The important development of ancient volcanic rocks in eastern Massachusetts, in the neighborhood of Boston, has been more discussed than any other similar region on this continent. An excellent résumé of the development of opinion regarding these rocks has been given by Whitney and Wadsworth.[3] E. Hitchcock held correct views as to the igneous character of all the massive rocks, although he regarded the amygdaloids and some of the apparently stratified felsites as altered sediments. Later the influence of Hunt created a general impression that the greater part of these rocks—even the granites—were of sedimentary origin. Wadsworth was the first to successfully combat this idea, and to show that not only were the coarsest massive rocks igneous masses, but even the finer jaspery felsites and their

[1] Bull. Geol. Soc. Am., Vol. 2, p. 138, 1891.
Report of the Geol. Survey of Canada, 1890–91, F. p. 75.

[2] See Geology of New Hampshire, Vol. 2, p. 260, and Vol. 3, part IV., Mineralogy and Lithology, p. 171, 1878.

[3] The Azoic System, pp. 398–44c, 1884.

accompanying fragmental materials were the products of ancient volcanic action. He maintained that the felsites of Marble Head were merely altered rhyolites which had once been quite like those of the western Cordilleras ; and their banding was flow-structure ; and that they were accompanied by ash beds which he called *porodites*.[1] Two years later the detailed work of Diller and Benton established the volcanic character of the felsites of Medford, Melrose, Malden, Sangus, Wakefield and Lynn, and of the amygdaloid of Brighton.[2]

Other areas of similar rocks occur near Newburyport, and also to the south of Boston at Needham, Dedham, Milton, Blue Hill, Hingham, Nantasket and Manomet,[3] but these have not as yet been so carefully examined as those farther north, although Crosby, in his recent "Geology of Hingham," classes the melaphyre. porphyrite, and felsite of Nantasket and Hingham as effusive or volcanic rocks, and describes the latter as "undoubtedly an ancient, devitrified obsidian."[4]

The Middle Atlantic States.—In New York state there are, as far as the writer is aware, no remains of igneous rock which have solidified at the surface. Nevertheless, the isolated and

[1] The Classification of Rocks. Bull. Mus. Comp. Zoöl., Harvard Coll., Vol. 5, p. 282, 1879. It is worthy of note, in view of all the erroneous ideas that have prevailed regarding the Boston felsites, that as early as 1822, Dr. Thomas Cooper, President of the College of South Carolina, in an article on "Volcanoes and Volcanic Substances" says: "No person accustomed to volcanic specimens can look at the porphyries from the neighborhood of Boston, in my possession, and doubt of their volcanic origin." (Am. Jour. of Science, 1st ser., Vol. 4, p. 239).

[2] "The Felsites and Their Associated Rocks North of Boston," by J. S. DILLER, Bull. Mus. Comp. Zoöl., Vol. VII., p. 165, 1881 ; and "The Amygdaloidal Melaphyre of Brighton, Mass.," by E. R. BENTON, Ph.D., Proc. Bost. Soc. Nat. Hist., Vol. 20, pp. 416–426, 1880. The writer is indebted to Mr. Diller for the privilege of examining his collection of slides of the Boston rocks which are in all essential respects identical with those from the coast of Maine, from South Mountain and North Carolina.

[3] E. HITCHCOCK : Final Report on the Geology of Massachusetts, Vol. 1, p. 150, 1841 ; W. O. CROSBY : Geology of Eastern Massachusetts, pp. 79–95, 1880.

[4] Proc. Bost. Soc. Nat. Hist., Vol. 25, p. 502, 1892. See also by the same author : The Lowell Free Lectures on the Physical History of the Boston Basin, 1889 ; and the Geology of the Boston Basin, Vol. 1, Part 1. Occasional Papers of the Boston Soc. Nat. Hist., IV., 1893.

highly differentiated "Cortlandt Series," near Peekskill, presents us with the deeply eroded roots of an ancient volcano, probably of Cambrian or Silurian age, whose superficial parts have entirely disappeared.[1] The eleolite-syenite area in northern New Jersey is probably of the same character.

In Pennsylvania and Maryland we find in the South Mountain or Blue Ridge, between Harrisburg and the Potomac, one of the most highly diversified and perfectly preserved areas of pre-Cambrian volcanic rocks in the world. Its position is established as below the Olenellus sandstone; it presents both acid (rhyolitic) and basic (basaltic) types; it exhibits within limited shear-zones the plainest effects of dynamic action, but its great mass is nevertheless so little changed that each microscopic structure of glassy rocks is clearly recognizable. Skeleton crystals, minute pores and larger vesicles, protoclastic breaking of the phenocrysts, fluidal structures of every kind, trichites, spherulites, axiolites, lithophysal and perlitic parting have lost none of their original sharpness, in spite of the complete devitrification of the glassy base. Most of the rocks were probably always wholly or mostly crystalline, but some regions, like the Bigham Copper and Raccoon Creek, display the old spherulitic obsidians and pumice in a manner allowing of no doubt. The pyroclastic materials accompanying these old lavas are also finely developed—ash-beds, coarse and fine flow- and tuff-breccias, etc. The precise centers of eruption within this region have not yet been definitely located, but with what has already been published regarding these rocks and the further details which may be soon expected, no further description of them is here necessary.[2] The entire misunderstanding of these rocks by Rogers, Hunt, Lesley and Fraser, who interpreted them as altered slates and their secondary cleavage as bedding, has greatly retarded the solution

[1] PROFESSOR DANA once suggested that the Cortlandt massive rocks might have been formed by the metamorphism of "volcanic debris or cinders" (Am. Jour. of Science, 3d ser., Vol. 22, p. 112, Aug. 1881), but he subsequently admitted their intrusive character (ib. Vol. 28, p. 384, Nov. 1884). See also opinions of the present writer (ib. Vol. 36, p. 268, Oct. 1888).

[2] Am. Jour. of Science (3rd ser.) Vol. 44, December, 1892, and Vol. 46, July, 1893.

of the geology of South Mountain, and has for many years invested it with a reputation for complexity which it in no way deserves.[1]

In Maryland and Virginia the acid and basic lavas and tuffs of South Mountain are extended southward as an important element in the composition of the Blue Ridge. They have been somewhat studied by the writer in this region and have been mapped and described by Keith.[2] This author mentions two quartz-porphyry areas showing flow-structure and tuffs, the larger between Catoctin and Blue mountains in Maryland, and the smaller near Front Royal in Virginia. He says that the diabase shows many indications of being a surface flow, and that it extends along the Blue Ridge from Maryland half way across Virginia, with an average width of twenty miles.

Southern States.—Volcanic rocks are largely developed in the central portion of both the Carolinas, as may be gathered from the old reports of Emmons and Lieber. During the past summer the writer had the opportunity of examining the belt in Chatham and Orange counties, North Carolina, in company with the State Geologist, Professor J. A. Holmes. The time at command was inadequate for the thorough exploration of the volcanic belt which skirts the western edge of the Triassic sandstone, but in a drive from Sanford to Chapel Hill an abundance of the most typical ancient lavas, mostly of the acid type, was encountered. On the road from Sanford to Pittsboro purple felsites and porphyries showing spherulites and beautiful flow-structures, and accompanied by pyroclastic breccias and tuffs, were met with two miles north of Deep river and were almost continuously exposed to Rocky river. Here devitrified acid glasses with chains of spherulites and eutaxitic structure were collected, while beyond as far as Bynum on Haw river, four miles northeast of

[1] See J. P. LESLEY: Summary Final Report, Penn. Geol. Survey, Vol. 1, p. 151, 1892.

[2] American Geologist, Vol. 10, pp. 366–68, December, 1892. Geologic Atlas of the U. S., Harper's Ferry Sheet (*in press*). For their distribution in Maryland see the Geological Map of the State, edited by G. H. WILLIAMS, and published in the World's Fair Book "Maryland," Baltimore, 1893.

Pittsboro, the only rocks seen were of the same general character. On the farm of Spence Taylor, Esq., in Pittsboro, a bright red porphyry with flow lines is exposed in so altered a condition that it can be easily cut into any form with a knife, though it still preserves all the details of its structure. It looks not unlike the well known pipe-stone, or Catlinite of Minnesota. Three quarters of a mile beyond Pittsboro on the Bynum road there is a considerable exposure of a basic amygdaloid. South of Hackney's Cross Roads there are other excellent exposures of the ancient rhyolites with finely developed spherulitic and flow-structures. Numerous specimens were here collected which place the character of these rocks as surface flows beyond a doubt. Another locality in the volcanic belt was visited on Morgan's Run, about two miles south of Chapel Hill. Here are to be seen admirable exposures of volcanic flows and breccias with finer tuff deposits, which have been extensively sheared into slates by dynamic agency. Toward the east and north these rocks pass under the transgression of Newark sandstone. The accompanying sketch-map (Fig. 2) shows the relations of the above mentioned localities in Chatham and Orange counties, N. C. From still another locality at the cross-road near the northern boundary of Chatham county, fifteen miles southwest of Chapel Hill, Professor Holmes informs me specimens of undoubted volcanic rocks have recently been secured; he has also sent to me within the past month a suite of similar specimens from Pace's Bridge on Haw river, three miles above Bynum.

In his upper division of the Taconic System in North Carolina, Emmons describes numerous beds of "chert or hornstone" intercalated in the slates and sometimes forming isolated bosses, whose origin he is at a loss to account for. He says they are not metamorphic, but does not suggest for them an igneous origin.[1] The hypothesis that these rocks may also be of volcanic origin is sustained by Emmons' description of "brecciated conglomerates" associated with the chert beds, which are composed

[1] Geological Report of the Midland Counties, N. C., 1856, pp. 66–68.

of an argillaceous or chloritic base, containing angular chert fragments of all sizes up to two feet. He mentions many localities

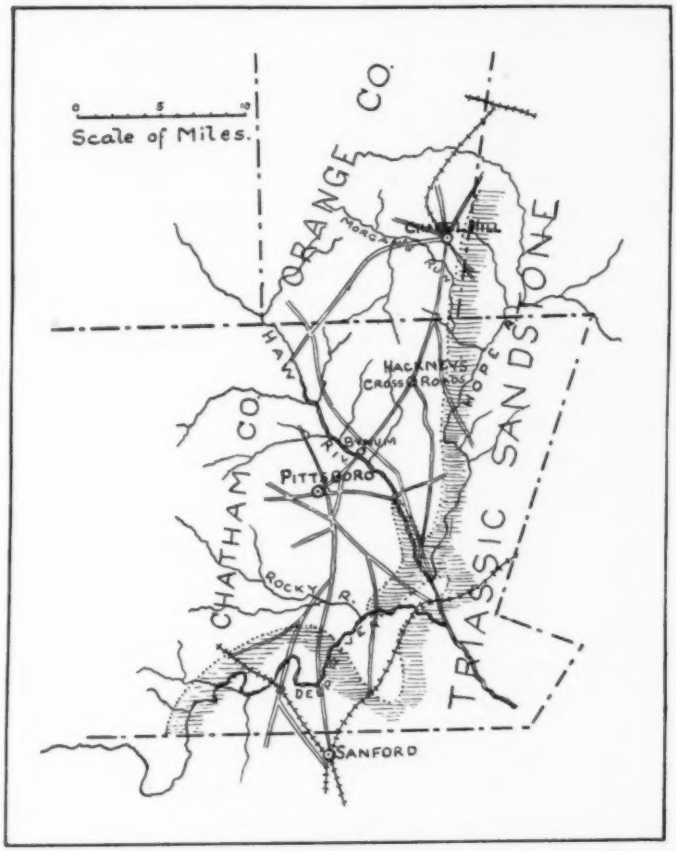

FIG. 2.

FIG. 2. Sketch map of parts of Chatham and Orange counties, N. C., showing localities for ancient volcanic rocks.

for these rocks, most of which are near the Yadkin river in Davidson, Rowan and Montgomery counties.

I am informed by Mr. Arthur Keith that he discovered a

large area of quartz-porphyry in the Great Smoky Mountains in Yancey Co., N. C., during the past summer.

The geological reports on South Carolina, by Lieber, describe a great development of igneous rocks which cross the state in the continuation of the North Carolina volcanic belt and which are themselves very probably in part of surface origin. His first report for 1856, which treats of Chesterfield, Lancaster, Chester and York counties, mentions among other more coarsely granular igneous rocks, eurite or quartz-porphyry, aphanitic-porphyry and melaphyre.[1] The counties of Union and Spartanburg, dealt with in Lieber's second report, are much poorer in igneous rocks, though he here adds the types schistose aphanite and minette. On the geological map of South Carolina, published by the Department of Agriculture in 1883, the belt of aphanitic greenstones and porphyries is shown to be continuous across the state in a southwest direction, and the statement is made that the greenstones predominate toward the north, and the porphyries toward the south, in Abbeville county.

Upon an expedition undertaken at the instigation of the writer, Prof. S. L. Powell of Newbury, S. C., found at Chester abundant eruptive rocks (granites and diorites), but none of unmistakably volcanic origin. At Lancaster, on the other hand, he found amygdaloids and felsites, showing distinct flow-structures which are certainly of igneous origin and could only have solidified at the surface.

In Georgia and Alabama nothing can be stated with certainty in regard to ancient volcanic rocks as the crystalline portions of these states have not as yet been petrographically investigated. The porphyry area of Abbeville county, S. C., is probably continued into Georgia. One single specimen of quartz-porphyry showing a beautiful micropoikilitic structure, collected in northwestern Georgia near the Tennessee line, has already been mentioned by the writer.[2] A box of specimens kindly sent

[1] Report on the Survey of South Carolina for 1856, 2d ed., Columbia, 1858, p. 31. Lieber had the German ideas regarding igneous rocks and their nomenclature. His "trachyte," "domite" and "phonolite" are probably fine grained varieties of the acid volcanic types.

to me for examination by Professor Eugene Smith of Alabama, proved to contain nothing which could be identified as ancient volcanic material.

GENERAL CONCLUSIONS.

The above rapid survey of the now known and probable areas of ancient volcanic rocks in the crystalline portion of the Appalachian system reveals the fact that this class of material is both abundant and widely distributed. From Newfoundland to Georgia it has been identified. For many areas the evidence of surface or volcanic origin is conclusive, while in many others it is as yet only probable.

The areas of these ancient volcanic rocks now known fall roughly in two parallel belts (see map); of these the eastern embraces the exposures of Newfoundland, Cape Breton, Nova Scotia, the Bay of Fundy, Coast of Maine, Boston basin and the central Carolinas; while the western belt crosses the Eastern Townships and follows the Blue Ridge through southern Pennsylvania, Maryland, Virginia, North Carolina to Georgia.

The purpose of the present communication will be accomplished if it succeeds in directing attention to this group of rocks. New areas should be added; probable areas investigated; and known areas monographed all along this old mountain range. How fruitful a field is here spread out to students of geology and petrography may be seen from the results of work in analogous regions by Harker[2] and Mügge.[3]

The identification of truly volcanic rocks in highly or partly crystalline terrains possesses far more than a petrographical significance, since by fixing what was the surface at the time of their formation, they furnish a certain datum for tracing out the sequence of later geographic changes and geological development.

GEORGE HUNTINGTON WILLIAMS.

[1] Am. Jour. of Science (3d ser.) Vol. 46, p. 47, July, 1893; and this Journal, Vol. 1, p. 179, 1893.

[2] The Bala Volcanic Series of Caernarvonshire, Sedgwick prize essay for 1888, by A. HARKER, Cambridge, 1889.

[3] Untersuchungen über die "Lenneporphyre" in Westfalen und den angrenzenden Gebieten by O. MÜGGE. Neues Jahrbuch für Min., etc., Beilage Band viii., pp. 525–721, 1893.

REVOLUTION IN THE TOPOGRAPHY OF THE PACIFIC COAST SINCE THE AURIFEROUS GRAVEL PERIOD.[1]

INTRODUCTION.

IT is now generally recognized that rivers are the architects and sculptors of their own valleys. The land is everywhere shaped largely by its streams, and the forms developed are serial, beginning with the river's youth and changing in the progress of time until finally the stream attains old age, and its topographic work is completed. In their early life, when rivers have their highest grade, they wash away their beds more than their banks, and cut cañons. Their beds are a succession of gentle flows, rapids, and falls, over the softer and harder beds. When by deep cutting the fall of the stream is reduced, it tends to spread out and erode its banks, the cañons widen, and the divides become narrow and sharp, with rugged peaks showing the stream's maturity, but the work of the fluvial sculptor still continues, and the mountains are reduced to hills and the hills to knolls so low that the general aspect of the country is that of a plain. The streams are powerless to erode the land below the level of this gentle plain, which has been appropriately named by Powell the Baselevel of Erosion. Thus in a complete cycle of a river's history the cañon and the broad divide, or plateau, are features of its youth; narrow, sharp, more or less rugged divides of its maturity, and the baselevel of its old age. The cañons have then disappeared, and the land reduced by long continued erosion approximately to sea level.

The development of the baselevel begins upon the seashore

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by which the level is determined, and gradually spreads inland toward the principal divides. Under similar conditions the shales and limestones wear away more rapidly than the coarser sediments and crystalline rocks, and local baselevels appear for a time determined by the harder rocks. But these are all obliterated in a general baselevel when it is completely developed. The land is so unsteady that it rarely, if ever, remains without elevation or depression long enough for the complete development of a baselevel of erosion. It commonly happens, however, that the large masses of harder rocks upon the slopes of the principal divides form independent elevations in the plain which may be more or less distinctly defined upon the softer rocks. The topography of the region is then essentially a peneplain.

It is evident that a general baselevel of erosion must have originated approximately at sea level. This is the only position in which a very extensive baselevel of erosion can originate. If we now find such a baselevel at considerable elevation above the sea, its position furnishes evidence that since the baselevel was formed the country has been uplifted in the process of mountain building.

Upon our Atlantic slope, ancient baselevels of erosion are well developed in the Piedmont region and elsewhere at considerable altitudes above the sea, as shown by Davis, McGee, Willis, Hayes, and Campbell. The ancient mountains have been swept away, and the modern mountains, at least in large part, are the result of later upheavals. Similar changes have taken place on the Pacific slope. Russell found in the St. Elias range, at an elevation of over 5,000 feet, shells of marine mollusks still living along the Pacific coast, showing that the great mountain range had been uplifted in very late geologic time. So, also, the Sierra Nevada and Coast ranges, and to some extent the Cascade range, now such prominent features of the Pacific coast, have been upheaved to their present great height, and deep cañons cut upon their slopes in the later geologic ages. At an earlier epoch the whole country was comparatively low and near sea level, or, in other words, near its baselevel of erosion. The mountain

ranges were then inconspicuous and the slopes everywhere gentle.

It is the object of this paper to trace out this ancient topography and briefly to outline the great changes by which the present features were developed. Incidentally the auriferous gravels will be considered, because they originated in large part at the beginning of its topographic revolution, which has on this account a most important economic interest.

TOPOGRAPHY OF THE PACIFIC SLOPE.

There are two prominent topographic belts on the Pacific slope. One is the platform of the interior basin region, and the other the mountain belt which lies upon the border of the continent. The latter embraces the Sierra Nevada, Cascade, and Coast ranges, as well as the Klamath Mountains in northwestern California and southwestern Oregon, where all the ranges meet. Between the ranges to the southward of the Klamath Mountains lies the Great valley of California, and to the northward the Sound valley extends from central Oregon across the state of Washington. The mountains are everywhere deeply cañoned by the rivers, but if we take a more general view, overlooking those features which are still developing, we shall discover others of much greater antiquity.

ANCIENT BASELEVEL OF EROSION.

Upon the northwestern and northern border of the Sacramento valley.—Upon the northwestern border of the Sacramento valley is a well-marked plain of erosion, which extends for nearly one hundred miles from about the 40th parallel around the northern end of the Sacramento valley to near the Great Bend of Pit river. It varies from one to fourteen miles in width, and is best marked in the Greasewood and Bald hills of Tehama and Shasta counties. The larger portion of the plain has been carved upon the upturned edges of the Cretaceous strata, and the denudation has reduced the thick, hard conglomerates and sandstones to the same level as the soft shales. At a number of places the well-defined plain extends for several miles into the area of harder

and more durable metamorphic rocks of the Klamath Mountains. Excellent views of this plain may be obtained from the Red Bluff and Hayfork stage road, five miles northwest of Hunter's postoffice, and from the mountain roads and trails leading westward from Stephenson's, Miller's, Lowrey's, and Paskenta, in Tehama county.

In the Klamath Mountains.—The plain already noted lies at the southeastern base of the Klamath Mountains, and passes by gradual and rapid transition into the steeper slopes of the mountains in such a way as to indicate that the plain may have once extended across the region now occupied by the Klamath Mountains. Within that group the plain has been recognized thirty miles southeast of Humboldt bay, about Shower's pass, at an altitude of nearly 4,000 feet, and a little farther east, in the even crest of South Fork Mountain, at an altitude of 6,000 feet. Major J. W. Powell informs me that he has observed a deformed baselevel in the Coast Range north of San Francisco. It will doubtless yet be found at many points, but on account of the great deformation which has taken place in the Klamath Mountains and Coast Range since the baselevel was formed, it is difficult to trace.

On the western slope of the Sierra Nevada.—The baselevel we have followed from Elder creek to Pit river was evidently determined by a body of water occupying the Sacramento valley, and traces of a corresponding level might be expected along the opposite shore about the Sierra Nevada.

The western slope of that range may be briefly described as an inclined plane, interrupted only by the narrow cañons of the present streams. Professor J. D. Whitney graphically portrayed the region as follows: "To one standing on some point, not too elevated, but from which a good view of the surface of the country along the flanks of the Sierra may be had, its slope will appear to be quite uniform and unbroken to one looking along a line parallel with the general trend of the range. It will seem, provided the point of view be favorably selected, as if the whole region was a gently descending plain, sloping down to the Great valley at an angle of not more than two or three degrees. And

the slope of the Sierra is—in the mining region at least—quite moderate, for if we allow a rise of 7,000 feet from the lower edge of the foothills to the crest of the range, the distance between the two points being about seventy miles, the average rise is only 100 feet to the mile, which gives an angle of slope of less than two degrees. And if one ascends the Sierra, keeping on the divide between any two rivers in the mining districts, he will find himself, for most of the time at least, on what seems to be a plain with a very gentle rise. Let the traveler, however, turn and attempt to make his way across the country, in a line parallel with the crest of the range, and he will discover that this apparent plain is cut into by the gorges or cañons in which the present rivers run, in a most extraordinary manner; he will find it several hours' work to descend into one of these and rise again to the general level on the other side, even if assisted by a well-beaten trail. All along the western slope of the Sierra the streams have worn for themselves deep cañons, and it is these tremendous gorges which form the leading feature of the topography of the region. If the streams ran nearly on a level with the general elevation of the surface, the whole character of the mountain slope would be changed. This was formerly the condition of the drainage of the Sierra slope."[1] Concerning the topography of the same region, Mr. Ross E. Browne remarks that "at certain favorably located points an extended view is obtained of the Forest Hill and neighboring divides. Upon losing the effect of the detail, one receives the impression of a general uniformity in the grades of the summit-lines. These summit-lines appear as the remaining traces of a gently undulating plain, sloping regularly from the bases of the massive peaks of the Sierra to the Sacramento valley."[2] Extended views of the western slope of the Sierra Nevada may be obtained at many points from the Central Pacific railroad between Colfax and the summit, and they fully illustrate the feature referred to.

[1] Auriferous Gravels of the Sierra Nevada of California, by J. D. WHITNEY. Pp. 63-64.

[2] The Ancient River Beds of the Forest Hill Divide. Tenth Annual Report of the State Mineralogist of California, 1890, p. 435.

This uniformity of gentle slope is enhanced in some cases, especially in the region of the American and Yuba rivers, by the broad, flat-topped lava flows which occupy the divides between the cañons. Sometimes it appears that the volcanics are thin, while at other places, according to Whitney their thickness is very large, quite often reaching 400 or 500 feet, and occasionally much exceeding that amount. The plain, however, is not limited to the areas occupied by volcanic rocks, but has a wide distribution over areas of closely folded auriferous slates, and cannot be attributed to the constructive effects of volcanic eruptions.

Mr. Gilbert was the first to call attention to the fact that this uniform surface is due to erosion upon a system of plicated strata, and "could only have been accomplished by streams flowing at a low angle,"[1] in other words, the plain must have originated essentially as a baselevel of erosion.

Judging from the topographic maps recently prepared for the geological work in the gold belt, as well as from the observations of Whitney,[2] Petty,[2] Goodyear,[2] Lindgren,[3] Turner, and myself, it appears that the inclined plateau which now forms the western slope of the Sierra Nevada was originally not worn down to so complete a plain as that already described upon the western side of the valley.

Mr. Lindgren (l. c.) says, "that the Sierra Nevada, before the accumulation of the gravels began, was a mountain range greatly worn down by erosion, but not reduced to a baselevel of erosion. It cannot even, on the whole, be regarded as a peneplain, above which isolated and more resistant hills projected. The declivities and irregularities of the old surface are too considerable for that, nor are the projecting hills invariably composed of the hardest rock-masses."

While some of the irregularities now recognized in the old plain upon the western slope of the range are due, as urged by

[1] Science, Vol. 1, p. 195, March 23, 1883.

[2] Auriferous Gravels of the Sierra Nevada of California.

[3] Two Neocene Rivers of California. Bull. Geol. Soc. of America, Vol. 4, p. 298.

Mr. Turner, to protruding hard rocks, it is possible that a considerable portion resulted from deformation when the Sierra Nevada was upheaved. For it will be shown later on that since this peneplain was formed by erosion, the Sierra Nevada has been greatly uplifted, and it would be very remarkable indeed if in the upheaval of such an enormous mass as the Sierra Nevada the original plain of its western slope were not warped and broken.

Platform of the interior region.—The fact that the baselevel plain passes to the eastward from the northern end of the Sacramento valley beneath the lavas of the Lassen Peak district, suggests that it may reach the platform of the interior region, which is now covered by volcanic material. Within northeastern California and the adjacent portion of Oregon there are vast stretches of level plains which are nearly of the same altitude above the sea. As far as known, all the surrounding hills and mountains are of lava. There are no projecting peaks of older rocks, and their absence from wide stretches of plateau country tends to show a general level of the subjacent surface analogous to that of the interior plateau in British Columbia described by Dr. G. M. Dawson.

The erosion plains we have traced upon the borders of the Sacramento valley, in the Klamath Mountains, upon the western slope of the Sierra Nevada, and probably also in the interior region of northeastern California, join one another in such a way as to show that they are simply different portions of one extensive baselevel of erosion which formerly spread over a large part, if not the whole, of middle and northern California and the adjacent portion of Oregon. What is the geological age of this plain of erosion?

DEPOSITS UPON THE BORDER OF THE ANCIENT BASELEVEL.

General statement.—In order to determine the conditions under which the baselevel was developed, and its age, it is necessary to study the formations deposited during its development. At the eastern edge of the baselevel, in the Sacramento valley, there are three formations, all of which were more or less

influenced by it in their distribution. Only two of these, the middle and the lower, need here be considered. The middle formation is a tuff which has already been called the Tuscan tuff. Below the Tuscan tuff and above the Cretaceous are gravels, sands, and clays, which apparently occupy the exact taxonomic position of the Ione formation of Becker, Lindgren,[1] and Turner, and may therefore be appropriately designated by the same name.

Tuscan tuff.—The Tuscan tuff is composed wholly of volcanic material. It will be considered first, for the reason that it can be most easily identified in different localities, and can be used to great advantage as a reference plane in considering the Ione.

On the western border of the Sacramento valley the most southern exposure yet observed is on Thomes creek, four miles east of Paskenta. From this point it has been traced with varying thickness for fifty miles across all the streams, cutting the eastern margin of the baselevel from Elder creek to Redding. It continues, with interruptions, around the northern end of the Sacramento valley to the thick deposits of similar material in the Lassen Peak region. It thins out to the westward and laps over on the baselevel in such a way as to indicate that the baselevel was formed before the great volcanic eruption which gave birth to the tuff.

Ione formation.—Beneath the Tuscan formation lies the Ione, which rests upon the upturned and eroded edges of the Cretaceous (Shasta-Chico) strata with conspicuous unconformity. In the Bald Hills region, northeast of Paskenta, it is composed of clay, and thins out rapidly to the westward against the edge of the baselevel. Farther northward the formation thickens somewhat, and contains much gravel, but everywhere it thins out rapidly to the edge of the baselevel. In the Lassen Peak region, beneath the lava, it has its greatest development, and is many hundreds of feet in thickness. To the northeastward it borders

[1] Geological Atlas of the United States. Text accompanying the Sacramento sheet.

upon the baselevel of the Klamath Mountains, while in the opposite direction it appears to stretch up to the high plateau at the northern end of the Sierra Nevada, and shows the features already noted of tapering abruptly to the edge of the baselevel plain. This formation might be considered a fringe to the baselevel, and evidently was deposited at least in part during the baselevel period.

The earlier auriferous gravels upon the slopes of the Sierra Nevada are older than the volcanic flows of the same region. They are regarded by Messrs. Turner and Lindgren and the writer as of essentially the same age as the Ione formation in the Great valley of California. The auriferous gravels were accumulated and deposited upon the flanks of the range, while the finer material, sand and clay, were carried into the Sacramento valley.

AGE OF THE BASELEVEL OF EROSION.

The age of the baselevel must be determined by reference to the formation with which it is associated. It is evidently of more recent origin than the Cretaceous, since it truncates the upturned edges of the Shasta-Chico series, and these are the youngest strata upon which it has yet been seen. It was already developed at the time the earlier auriferous gravels were deposited, for they lie in the broad shallow valleys which belong to the baselevel plain. The erosion by which it was developed therefore occupied a part or the whole of the time interval between the upheaval of the land at the close of the Chico epoch (Cretaceous) and the deposition of the auriferous gravels.

The age of the earlier auriferous gravels has not yet been fully determined, although they have been the subject of much investigation. That of the later gravels will not be considered here. Professor J. D. Whitney, in his "Auriferous Gravels of the Sierra Nevada of California," page 283, says: "It appears probable, on stratigraphical grounds, that the detrital beds overlying the bed rock of the Sierra Nevada represent the whole

Tertiary period, that is, that they have been forming since the beginning of that epoch.[1] . . . The evidence of the geological age of the gravel deposits afforded by the plants found in the sedimentary beds underlying the latest eruptive masses in the mining region of the Sierra has already been discussed by Mr. Lesquereux. He distinctly recognizes the presence in this flora of forms identical with or closely allied to those of the Miocene; but still calls the age of the group Pliocene. Something of the same kind seems to be legitimately inferred from the animal forms of the same deposits. There are certain fossils which have been found only in deep-lying gravels like those of Douglas Flat and Chili Gulch. No traces of the rhinoceros, the elotherium or the small equine animal referred with doubt by Leidy to Merychippus have ever been found in deposits which could by any possibility be proved to be more recent than the basaltic overflow. It is true that the evidence thus far collected is but fragmentary. Still, taking it for what it is worth, it may be said that the affinities of these animals found in these lower deposits would indicate a Miocene rather than a Pliocene age. There are also, it is believed, stratigraphical reasons for admitting that some at least of the deposits containing these older fossils may be proved by other than palæontological evidence to belong to an older series than those strata which, though anterior to the basalts, yet contain a fauna decidedly mere Pliocene than Miocene in character."

A collection of plants made from the older auriferous gravels upon the northern end of the Sierra Nevada was examined by Professor Lesquereux, who reported that their relation is evidently to the Miocene (U. S. Geological Survey, Eighth Annual Report, p. 419). Professor L. F. Ward, who examined the same collection, agreed that they were Miocene, most likely upper Miocene.

Recently the evidence afforded by the plant remains has been

[1] By the Geological Survey of California the Tejon was regarded as Cretaceous. Palæontology, Vol. 2, p. xiii. It is now regarded as Eocene, and in Oregon lies unconformably on the Shasta-Chico series.

ably reviewed by Professor F. H. Knowlton, who studied extensive collections from the auriferous gravels of Independence Hill, Placer county, California. He concludes that the gravels are probably upper Miocene in age.[1]

On stratigraphic grounds the auriferous gravels are regarded as contemporaneous with the Ione formation of the Sacramento valley, but here, too, as in the earlier auriferous gravels, the fossil plants and shells appear to indicate that they belong to the Miocene.

That the approximate baselevel reached its greatest development about the time the earlier auriferous gravels were deposited is indicated by the fact that they lie in the broad shallow valleys of that plain. The present tendency of the organic evidence contained in the flora of these gravels is to indicate that their deposition took place during the Miocene, most likely later Miocene. The erosion necessary to develop the baselevel out of the topography resulting from the uplift at the close of the Shasta-Chico period must have occupied a long interval of time, possibly beginning in the latter part of the Cretaceous and continuing through the Eocene and earlier portion of the Miocene, but as the plain appears to have attained its maximum extent during the Miocene, it may be referred to as the Miocene baselevel.

THE ELEVATION INDICATED BY THE FLORA OF THE AURIFEROUS GRAVELS.

The flora of the region indicated by the remains found in the earlier gravels is of special interest on account of its bearing on the topography. Numerous fossil leaves have been found in the early auriferous gravels about the northern end of the Sierra Nevada at Mountain Meadows, near the summit of Spanish Peak and elsewhere on the very crest of the Sierra, at altitudes ranging from 2,900 to 6,350 feet above the sea. These plants were studied by Professor Lesquereux, who recognized among them three kinds of figs and a large number of lauraceous plants, with other forms of similar significance. Not a single species of pine

[1] U. S. Geological Survey, Bulletin 108, page 104.

or fir, such as constitute the prevailing arboreal vegetation of that region to-day was recognized in the collections.

In answer to a question concerning the climatic conditions of that region during the Miocene, as indicated by this flora, Professor Lesquereux stated that "by the presence of a large number of Laurineæ the flora becomes related in its general characters to that of a region analogous in atmospheric circumstances to Florida." With this view Professor Lester F. Ward fully agrees, and also Mr. F. H. Knowlton, who has lately given much attention to the flora of the auriferous gravels.

Mr. Knowlton, says "Lesquereux, as already stated, argued that the presence of a large number of lauraceous plants indicated a region analogous in atmospheric circumstances to Florida. From my own studies, which embrace a much larger amount of material than Lesquereux had, I am not only prepared to accept this statement but to show that it was even stronger than he could have made it out."

Florida is a comparatively low country, rising nowhere more than a few hundred feet above the sea, and it is reasonable to infer that during the early gravel period northern California, which was then analogous in atmospheric circumstances to Florida, could not have been a region of high snow-tipped mountains as it is to-day.

It is well known that during the Miocene tropical conditions extended much farther north than now, and under such circumstances it is possible that certain forms of plants may have had considerably greater range in altitude than their relatives in California have to-day.

No doubt the Sierra Nevada existed at that time, but was a very low range, at least in the northern portion, as compared with its present altitude. Yet it was high enough to supply the alder, birch, poplar, and willows, as well as the few pine leaves lately found by Mr. Turner.[1]

The evidence afforded by the flora of the region is in complete harmony with the inference drawn from the topographic

[1] Bulletin Philosophical Society of Washington, Vol. 11, p. 391.

relations, namely, that during the Miocene the country was a series of plains and peneplains with low mountain ranges, or in other words, the country was but little above its baselevel of erosion. In no other position could such extensive plains have been formed by erosion.

GEOGRAPHY OF NORTHERN CALIFORNIA DURING THE MIOCENE.

The Ione formation being well stratified was evidently laid down in a body of water having a distribution at least as extensive as the formation itself. In the Sacramento valley, as far north as Marysville Buttes, the water of the bay was salt, as shown by the marine shells found at that point by Mr. Lindgren.[1]

Upon the borders of this bay, at Ione, where the conditions were favorable for the accumulation of the vegetable matter to form lignite, the water was regarded as fresh or brackish. Farther northward only unios have been found, and the water in which the Ione formation originated was fresh. Beyond the Lassen Peak region in northern California the water was undoubtedly fresh, but whether one large lake or a series of lakes, or a water body connected directly with that of the Sacramento valley as an estuary from the sea, is a matter of doubt.

From the Great valley the sea swept across the region of the Coast Range, perhaps near the latitude of Sacramento, and extended northward over the area of the broad belt of sandstones upon the western slope to beyond Humboldt Bay. The borders of the land must have been low and swampy to make the conditions favorable for the accumulation and preservation of vegetable matter to form coal. The Sierra Nevada and Klamath Mountains themselves were low, with gentle slopes as compared with those of the present ranges, and the streams flowed down their flanks in broad, shallow valleys instead of in deep cañons as they do now.

[1] Geologic Atlas of the United States, text accompanying the Sacramento sheet. See also U. S. Geological Survey Bulletin, No. 84, by W. H. DALL and G. D. HARRIS, p. 197.

DEFORMATION OF THE BASELEVEL.

It is evident that since the Miocene there have been great changes of level in northern California, for instead of the original baselevel of the erosion, we have now prominent mountain ranges, whose sides are furrowed by the deep cañons of the rejuvenated streams.

The deformation of the baselevel may be studied along two lines of evidence: (1) by tracing the present variations of altitudes in the original baselevel, which must have had a very gently sloping surface itself, and (2) by tracing the deformation of the Ione deposit which, when laid down, must have been below sea level at a lower altitude than the baselevel, because deposited in the water body upon its border. Each line of evidence should corroborate the other and render conclusions concerning the deformation more trustworthy.

It is impossible to tell from what is known at present the original inclination of the baselevel. It is evident, however, that it must have been considerably less than one degree, for at that angle streams generally erode their beds much more than their banks, and cut cañons.

Upon the western edge of the baselevel, at the foot of the Klamath Mountains in Tehama county, the altitude is nearly 2,300 feet, while upon the eastern edge it is considerably less than 1,000 feet, giving the old plain in the Greasewood hills a slope of 100 feet to the mile to the eastward. Across this plain the present streams flow in cañons 300 to 400 feet deep, and they are still cutting. The cañons in general are deepest to the westward and gradually run out to the Sacramento river in the newer deposits which fill the valley. It is evident that since the baselevel was formed, it has been affected by differential elevation in the uplifting of the Coast Range and Klamath Mountains, just north of the fortieth parallel, to the extent of over 2,000 feet, and if we may judge from the traces of the baselevel seen at Shower's pass and South Fork Mountain, the upheaval in the Klamath Mountains has been much greater. It has long been

maintained by Whitney and others that the principal upheaval of the Coast Range occurred at the close of the Miocene.

At the northern end of the valley the elevation of the base level is 800 feet. To the eastward it rises gradually to 1,300 and 1,700, and finally in the neighborhood of Round Mountain to 2,500 feet, showing elevation in the Lassen Peak and Sierra Nevada region east of the Sacramento valley.

Mr. G. K. Gilbert[1] was the first to recognize the broad plateau upon the western slope of the Sierra Nevada as a plain of erosion, and discussed the matter in such a way as to show that the height of the range has been considerably increased since the erosion plain was formed.

Professor LeConte advocated essentially the same view. He says:[2] "The rivers, by long work, had finally reached their base levels and rested. The scenery had assumed all the features of an old topography with its gentle flowing curves. At the end of the Tertiary came the great lava streams running down the river channels and displacing the rivers; the heaving up of the Sierra crust block on its eastern side, forming the great fault-cliff there, and transferring the crest to the extreme eastern margin; the great increase of the western slope and the consequent rejuvenescence of the vital energy of the rivers; the consequent down-cutting of these to form the present deep cañons and the resulting wild, almost savage, scenery of these mountains."

The observations of Mr. W. Lingdren[3] in the region of the Yuba and American rivers upon the western slope of the Sierra Nevada, "appear to prove that the grades of the remaining Neocene gravel channels are to a certain extent determined by the directions in which they flowed, in such way as to strongly suggest that the slope of the Sierra Nevada has been considerably increased since the time when the Neocene ante-volcanic rivers flowed over its surface. It finally appears probable, from a study of the grade curves of the remaining channels, that the

[1] Science, Vol. 1, March 23, 1883, pp. 194–195.

[2] Bull. Geol. Soc. of Am., Vol. 2, pp. 327, 328.

[3] Bulletin of the Geological Society of America, Vol. 4, p. 298.

surface of the Sierra Nevada has been deformed during this uplift, and that the most noticeable deformation has been caused by a subsidence of the portion adjoining the Great valley relatively to the middle part of the range."

Strong evidence of the deformation is furnished by the distribution of the Ione formation. As already shown, this formation was deposited about sea level. On Little Cow creek it now occurs at an altitude of 3,400 feet, and on Bear creek about 4,000 feet above the sea, indicating conclusively that since the base-level period the Lassen Peak region has been elevated at least 4,000 feet. There are indications that the elevation was still greater to the southward about the northern end of the Sierra Nevada, for between Mountain Meadows and Diamond Peak opposite Susanville the auriferous gravels supposed to belong to the estuarine Ione formation rise from 5,000 to 7,000 feet. These high gravels upon the northeastern block of the Sierra Nevada have been displaced in a remarkable manner by the upheaval of the range. The area occupied by them is about 10 × 16 miles in extent. Although the gravels cover the larger part of this area and are connected throughout, they do not appear over the whole of it. There were a few small islands of older rocks during at least the later portion of the gravel period, and at some other places within the area the gravels have either been washed away or covered up by later volcanic flows.

During the later part of the gravel period in that region, after the effusion of the andesitic lavas, more or less well defined beaches were formed around a series of volcanic islands upon what is now the very crest of the range from Fredonia Pass northeast of Mountain Meadows to Diamond Mountain. When developed, these beaches must have been at the same level in a body of standing water, but now they gradually rise to the southward from about 5,000 feet near the northern end of Mountain Meadows to 7,000 feet opposite Diamond Peak, and it is evident not only that the northern end of the range has been elevated but that the amount of elevation increased to the southward. The general inclination of this body of gravels toward Lassen

Peak, beneath whose lavas it disappears, makes it very probable indeed that they are connected with the Ione formation that disappears under the opposite edge of the same lavas bordering upon the eastern side of the Sacramento valley. If this could be definitely established it would show that the northern end of the Sierra Nevada has been elevated 7,000 feet since the gravel period of that region. It is possible that the increased elevation does not extend far to the southward, for beyond the 40th parallel the eastern crest of the range retreats to the escarpment of the main block of which the Sierra Nevada is composed.

In connection with the upheaval of the northeastern portion of the range a fault was formed along the eastern base at least beyond Honey Lake. A short distance above Janesville the gravels are displaced by a fault in which the throw is about 3,000 feet. On the very crest of the range, seven miles northwest of Janesville, the gravel rises to 7,400 feet, while at the foot of the steep slope which it caps the same gravel occurs in Mr. Weisenberger's mine at an elevation of about 4,300 feet. To the northwestward the fault runs out apparently in a monoclinal arch, later than the volcanic eruptions on the crest of the range at that point,[1] but before the final eruptions of the Lassen Peak region were completed. Mr. Lingdren has shown[2] that further south the eastern slope of the range was formed before the eruption of the andesitic lavas. There is some evidence of a similar character in the Honey Lake Region.

ORIGIN OF THE EARLIER AURIFEROUS GRAVELS.

The Tejon epoch appears to have been brought to a close, and the Niocene initiated, in northern California, without any marked change of level, unless a general subsidence,[3] so that the influences in operation during the Tejon continued into the Miocene. The old streams still carried on their enfeebled erosion, and in some places the land was completely reduced to

[1] See also Eighth Annual Report U. S. Geological Survey, p. 429.

[2] Bull. Geol. Society of America, Vol. 4, pp. 257–298.

[3] DALL and HARRIS: U. S. Geol. Survey, Bull. 84, p. 278.

baselevel. The removal of material was chiefly by solution, and the insoluble residuary material thus set free by the disintegration of the rocks accumulated to considerable depths upon the land.

The long period during which the land of northern California remained comparatively stationary, and which enabled the streams in many parts of that region to practically complete their cycles of erosion from youth to old age, was brought to a close by the initiation of an orogenic movement which generally increased the grade of the streams upon the western slope of the Sierra Nevada. At first the differential change of level was very moderate and increased the declivity of the streams but little, but being long continued it became in time revolutionary in its effects, and finally, accompanied by extensive volcanic eruptions, gave birth to the High Sierra of to-day with the deep cañons upon its western slope.

The first result of this change of slope was to rejuvenate the streams and invigorate erosion. On account of surface deformation which must have accompanied the upheaval of such a large mass as the Sierra, the stream grades would be differently affected even along the same channel, and in fact, as Mr. Lindgren has pointed out, in at least one case, owing to direction of flow, the stream grade has been not only diminished but reversed.[1]

The country being covered by a thick coating of soft residuary material, of which the great mass was fine particles, erosion was easy. There were coarser fragments of quartz, largely vein matter, as well as boulders of disintegration which had withstood the chemical changes. The streams readily became loaded not only to their full capacity but overloaded with the mass of fine material, and were thus forced to deposit the coarser particles. The grains and fragments not quite suspendable under the conditions of load were rolled along the bottom and rounded by attrition.

In this way the old channels of the baselevel period became filled with gravel of which by far the larger part is quartz. In

[1] Bul. Geol. Soc. of Am., Vol. 4, p. 281.

the same way the gold, being heavy, and associated with the quartz originally, accumulated in the same channels, while the fine light detritus was carried directly to the Sacramento valley.

In his paper on the ancient river beds of the Forest Hill divide,[1] Mr. Ross E. Browne classifies the auriferous gravel channel systems into three periods. The first period was prior to the first important flow of volcanic cement, the second was contemporaneous with the series of volcanic cement flows, and the third following immediately after the last important flow of volcanic cement extends to the present time. He has called attention to the predominance of quartz gravel[2] and sand in the ancient channels of the first period, and remarks that "quartz is the only important material contained in the belts (of slates) which is hard and permanent enough to resist the destructive action of the current." This is especially true when the auriferous slates are disintegrated. It is possible therefore that the predominance of quartz in the earlier gravels may indicate an earlier period in which the slopes had less declivity and disintegration exceeded transportation.[3] The fact that in the Light's cañon region of Plumas county the gravel is underlain by a sheet of residuary material which was formed before the deposition of the gravel is evidence in the same direction. Furthermore, the sand deposited with the gravel is rough, angular and unassorted, such as is derived from residuary material near at hand, and records a period of gentler declivity during the next earlier epoch.

The old channels of auriferous gravel of the first period are in a measure characterized by the large size of the deposits. Ross E. Browne states:[4] "In a general way it may be said that the channels of the second period differ from those of the first as

[1] Tenth Annual Report, State Mineralogist of California, 1890, pp. 437-439.

[2] See also J. D. WHITNEY's Auriferous Gravels of the Sierra Nevada, page 323, who says "that in some localities the gravel is almost entirely made up of quartz boulders and pebbles."

[3] Mr. BAILEY WILLIS some time ago, in his study of the Appalachian region, came to a similar conclusion, yet unpublished, to account for the predominance of quartz pebbles in the conglomerate at the base of the Coal Measures.

[4] Tenth Annual Report State Mineralogist of California, pp. 439–441.

follows: their beds are narrower, rims steeper, and accumulations of bed rock gravel incomparably smaller." In these large accumulations of older gravels Prof. Whitney saw evidence of larger streams and heavier precipitation during the gravel period than now belongs to that region,[1] but, as pointed out by Mr. Gilbert,[2] deposition in stream channels is indicative of diminished instead of increased rainfall.

Professor Le Conte regarded the gravels as "deposits made by the turbulent action of very swift, shifting, overloaded currents" supplied with both water and debris "by the rapid melting of extensive fields of ice and snow" which were then supposed to occupy the higher portion of the range.[3]

A very important contribution to the literature of the auriferous gravels has been made lately by Mr. W. Lindgren, whose views are expressed in the following quotation:[4]

"From the rugged country in the region of their sources the rivers pursued their course down in broad valleys separated by ridges which even in the lowest foot-hills sometimes reached an elevation of a thousand feet above the channels. The outlines of the ridges were usually comparatively gentle and flowing; still, slopes of ten degrees from the channel to the summit were common and slopes as high as fifteen degrees occurred in the eastern part of the Sierra. The character of a region of old and continued erosion, commencing probably far back in the Cretaceous period, is everywhere plainly evident. In the center of the deep depressions is quite frequently found a deeper cut or "gutter," indicating a short period of more active erosive power just before the beginning of the gravel period. At this time, probably about the beginning of the Miocene period, the streams became charged with more detritus than they could carry and began to deposit their load along their lower courses, especially at places favorably situated, as, for instance, along the longitudinal valley of the South Yuba. Toward the close of the Neocene, gravels had accumulated all along the rivers up to a (present) elevation of about 5,000 or 6,000 feet; above this it is plain that erosion still continued in places with great activity and furnished some of the material deposited in the lower parts of the streams. The coarse character of much of the gravel and

[1] Climatic Changes in later Geological Times, p. 1. See also Auriferous Gravels, p. 335.

[2] Science, Vol. I., p. 194, March 23, 1883.

[3] Am. Jour. Sci., Vol. XIX., 1880, p. 184.

[4] Bul. Geol. Soc. of Am., Vol. 4, pp. 265–6.

the often remarkable absence of fine sediments in the beds point clearly to a somewhat rapid stream capable of carrying off a great deal of silt, and the accumulations are probably due to rapid overloading rather than to low grades of the rivers. The deep channels were filled and the gravels encroached on the adjoining slopes, where they were deposited in broad benches. A maximum thickness of 500 feet of deposits was attained on the South Yuba, and of from 50 to 200 feet in the other parts of the lower rivers. In the lower and middle Sierra some of the rivers then meandered over flood-plains two or three miles wide, above which the divides of bed-rock rise to a height of several hundred feet. In some instances low passes over divides were covered, and temporary bifurcation and diversion of rivers into adjoining watersheds occurred."

It is evident from the facts already known that at the time the early gravels were deposited the northern end of the Sierra Nevada was not less than 4,000 feet lower than at the present time, and that its climatic circumstances as indicated by its flora were not such as to give rise to either glaciers or extensive fields of snow.[1] For this reason it is necessary to appeal to some other cause than glaciers as the source of the great mass of debris deposited in the old auriferous gravel channels, and in view of the facts herein cited, the writer suggests that a source may be found in the large mass of residuary material upon the surface at the beginning of the gravel period. There is evidence, as already shown, that at the close of the Tejon disintegration exceeded transportation, and residuary deposits accumulated upon the gentle slopes of the land to considerable depths. This condition appears to have continued during the early Miocene. The depth of disintegrated rock would vary greatly with different formations. Upon the diorite and other rocks containing minerals subject to ready alteration it would be deepest, and their surfaces, at least in the case of the diorite, would be strewn as to-day with large and small boulders of disintegration. The quartz veins which intersect these rocks and the silicious slates would be but little affected. The gold not enclosed in quartz veins[2] would be set free.

[1] See also WHITNEY's Auriferous Gravels, p. 295.

[2] WHITNEY's Auriferous Gravels, p. 352.

If, when thus mantled with residuary material, the Sierra Nevada region were affected by a change of level in such a way as to slightly increase the fall of the streams upon its slopes, it is believed, as already suggested, that during a comparatively brief period owing to overloading they would be forced to deposit and fill their channels. A portion of the process is, in a measure, illustrated by what has taken place along some of the present streams of the Sierra Nevada where hydraulic mining has been extensively carried on. The streams are overloaded by the debris forced into them from the mines and their channels are at least temporarily filled with gravel.

After the deposition of the earlier gravels the declivity of some of the streams at certain points appears to have been so decreased that they deposited finer material and covered the gravel with sand and clay. This may have resulted from differential elevation, differential subsidence, or both, and there is evidence that both occurred within the gravel period. At Cherokee Flat upon the eastern border of the Sacramento valley the finer, essentially estuarine deposits, over 300 feet in thickness, lap over to the eastward upon the ancient river and shore gravels mined at that place. This overlapping evidently resulted from a subsidence of that region.

SUMMARY.

A study of the ancient topographic features upon the borders of the Sacramento valley, in the Klamath Mountains, and upon the western slope of the Sierra Nevada, shows that during the earlier portion of the auriferous gravel period, southern California, by long continued degradation, was finally reduced approximately to baselevel conditions. The mountain ranges were low, and the scenery was everywhere characterized by gently flowing slopes.

The distribution of the Ione formation and the early auriferous gravels, as well as the plant remains which they contain, point clearly to the same conclusion.

The topographic revolution consisted in developing out of such conditions the conspicuous mountain ranges of to-day.

The northern end of the Sierra Nevada has since been raised at least 4,000 feet, and possibly as much as 7,000 feet, and a fault of over 3,000 feet developed along the eastern face of that portion of the range. The Klamath Mountains may in some portions have experienced at the same time an equal upheaval. From all sides the amount of uplift decreased rapidly toward the Sacramento valley.

In the initial part of this revolution the earlier quartzose auriferous gravels were formed. The source of their material was found in the thick deposits of residuary detritus which had accumulated upon the surface of the land during the baselevel period. This large accumulation of disintegrated rock substance rendered the loading of the streams so easy that when rejuvenated by orogenic movements they became overloaded and filled their ancient channels with auriferous gravels.[1]

J. S. DILLER.

U. S. GEOLOGICAL SURVEY, Washington, D. C.
December 12, 1893.

[1] Since this paper was written a very important one has been published by Prof. A. C. LAWSON, on the Post-Pliocene Diastrophism of the Coast of Southern California. University of California, Bulletin of the Department of Geology, Vol. I., No. 4, pp. 115-160.

THE NAME "NEWARK" IN AMERICAN STRATIGRAPHY:

A JOINT DISCUSSION.

I.

MUCH time and ink have been wasted in discussing the claims of alternative stratigraphic names. In many instances controversies arise over questions of fact, but there are also numerous cases in which the facts are well understood, and individuals disagree only as to the bearing of the facts on the questions of nomenclature. Opinions differ so widely as to the principles which should determine the selection of names that facts which some regard as conclusive appear to others not at all pertinent. The road to ultimate peace lies through a war of principles; and the valuable controversy is one in which the fundamental postulates of the contestants are exposed. Holding this view of the general question, I would be understood as joining in the discussion of the term "Newark" only because a principle of stratigraphic nomenclature appears to be involved.

In a recent article B. S. Lyman says:

"For those rocks have, from their conformability throughout, and their predominant color, and a comparative lack of fossils through a great part of them, been commonly lumped together as only a single group, formation, or system, under the general name of New Red, or Triassic, or Jurassico-Triassic, or Rhætic. Nearly forty years ago, with the bold assurance born of ignorance, perhaps quite pardonable at that time, the special name of Newark group was proposed for the whole lot, from one of its most striking local economic features, though otherwise an extremely subordinate one, and even economically perhaps inferior to the Richmond coal; and latterly there has been an effort to revive the name, long after it had fallen into well-merited oblivion."[1]

I am one of those who have seconded Russell's proposal to revive the name "Newark,"[2] and despite the brief argument

[1] Proc. Am. Phil. Soc., Vol. 31, p. 314.

[2] Am. Geol., Vol. 3, 1889, pp. 178–187.

which accompanies Lyman's protest, I am at present of opinion that the needs of geologists are better served by Newark than by New Red, Jurassic, Jurassico-Triassic, or Rhætic.

It may be assumed that there is no difference of opinion as to the propriety of giving local geographic names to the minor stratigraphic units. Such is the modern practice of most geological surveys, and it has the sanction of the International Congress of Geologists. Lyman, too, in the paper cited, introduces Pottstown shales, Lansdale shales, Norristown shales, Perkasie shales and Gwynedd shales as the names of newly recognized formations in eastern Pennsylvania and the contiguous parts of New Jersey, deriving the distinctive word in each case from the local geography. The stratigraphic units thus distinguished are all parts of the larger unit to which Redfield applied the local geographic name "Newark."

But Lyman protests against the use of the local name for the larger unit. It is not entirely clear to me whether he holds that the larger unit should have no name, or that it should not have a local name, or only that it should not receive the particular local name; and I therefore find it easier to state the basis of my own opinion than to discuss his view.

1. In my opinion *the larger unit should have an individual name*.—In the nomenclature of stratigraphy, as in language generally, it is advantageous to avoid paraphrases by giving a short name to every concept which needs frequently to be expressed. That for which Redfield proposed the name "Newark group"[1] is a stratigraphic integer, so definitely limited in nature that its individuality has been recognized in the literature of a half century. In the paper just referred to it is distinctly recognized by Lyman, who calls it in one place "the older Mesozoic rocks of New Jersey," and elsewhere "the older Mesozoic," "the so-called New Red," "the New Red beds," "the New Red." Each of these terms is used as a name rather than as a description; even the long phrase "the older Mesozoic rocks of New Jersey" is not a definition, for it is made to cover rocks, for example, the

[1] Am. Jour. Sci., 2nd ser., Vol. 22, 1856, p. 357.

Richmond coal, which are not in New Jersey. The unit is peculiarly definite in that its lower and upper limits are marked by conspicuous unconformities, while its strata are everywhere conformable with one another. Its composition, though not uniform, is so little varied that attempts to unravel its stratigraphy and structure have been successful in but few districts.

2. *The name should include a local geographic term.*—In the nomenclature of historic geology there are two parallel sets of terms, the one representing larger or smaller bodies of strata, the other representing larger or smaller divisions of geologic time. As the divisions of geologic time are based upon the classification of strata, their names have been mostly derived from stratigraphy, and there are many circumstances under which it is a matter of indifference whether a given term be construed in its stratigraphic or in its chronologic sense. Partly in this way there has arisen a widely prevalent habit of confusing strata and time. This confusion has an unfortunate influence on the treatment of problems of correlation, as it leads to language implying that the stratigraphic units of distant lands, for example, Europe and America, are the same. As I understand the case each portion of the general geologic time scale was based upon the stratigraphy of some district, usually in Europe. Correlation at a distance, for example, in America, does not determine the existence in America of the European formations, but only the existence of local formations deposited (in whole or part) in the same portions of geologic time. Or, in other words, correlation arranges the formations of a country in accordance with a standard time scale.

When the time relations of a formation or other stratigraphic unit are unknown or are imperfectly known, a name derived from the time scale can be employed only provisionally. As knowledge of fauna and flora increases, opinions change as to time relations, and experience shows that at any stage in the accumulation of paleontologic data conflicting opinions may be held by different students. Time names are thus unstable; but a geographic name, depending as it does on simple relations readily

ascertained, is permanent. The rocks in question well illustrate the confusing synonomy which arises from the employment of time names. They have been called at various times and by various writers: Silurian, Old Red, Carboniferous, Lower Carboniferous, Permian, Upper Permian, Mesozoic, Older Mesozoic, Secondary, Middle Secondary, New Red, Trias, Jura-Trias (and synonyms), Keuper, Upper Trias, Rhætic, Lias, Inferior Oolite, and Oolite.

When the chronological relations of a stratigraphic unit have been established, it becomes proper to apply to it the title of any time division including its period of formation; but the need for a local stratigraphic name, or, in other words, an individual name, does not cease. The place of the Hamilton group in the time scale is so well known that it is properly called Devonian and Paleozoic, but the local name Hamilton is still useful.

In the conceivable case of a formation or group representing the whole of a division of the time scale and no more, there might be a question of the need of a local name. But the existence of such a case has not been demonstrated, and it must be admitted that in the great majority of instances the local stratigraphic units are incommensurate with the standard time units. The body of rocks under consideration is imperfectly supplied with fossils, and little is known of the relations of its fossiliferous horizons to one another and to the upper and lower limits of the series. No one asserts that its period of formation was coëxtensive with any of the time divisions whose names have been provisionally applied to it. Opinions as to the interpretation to be given to its fossils are still divergent, and the only name which can be conveniently used by all is one which avoids the question of correlation. A local geographic name meets this requirement.

There are valid objections to a paleontologic or a purely petrographic name, but as such have not been proposed the objections need not be stated.

3. *The proper geographic term is Newark.*—Prominent among the qualifications of a geographic term for employment in strati-

graphy are (1) definite association of the geographic feature with the terrane, (2) freedom of the term from preoccupation in stratigraphy, (3) priority. The rule of definite association is satisfied if the geographic feature, being a town or district, is wholly or partly underlain by the terrane, or if, being a stream, it crosses the terrane. Preferably the portion of the terrane thus associated should be petrographically and paleontologically characteristic, but this consideration yields to priority.

The "Newark" rocks underlie the City of Newark, exhibiting typical phases of sandstone and shale and containing some fossils. The only other rocks present are of widely different character, being Pleistocene. The name Newark has been applied to no other terrane. It is the earliest geographic name proposed for this terrane.[1]

G. K. GILBERT.

II.

MR. GILBERT has very kindly invited me to answer his argument: (1) that the so-called Newark system ought to have a name, because it is a stratigraphic integer, or unit; (2) that a stratigraphic name ought to include a local geographical term; and (3) that the name Newark is the proper one, because of (a) the definite association of that geographical feature with the rock beds in question, (b) the freedom of the term from preoccupation in stratigraphy, and (c) its priority.

1. He considers that the stratigraphic unit is peculiarly definite from the conspicuous unconformities at top and bottom, while internally it is conformable throughout with little varied composition.

In eastern Pennsylvania, where the rock beds have been studied with some small approach to thoroughness, the composition is found sufficiently varied to justify at least five very conspicuously marked subdivisions of several thousand feet each. Almost all the fossils hitherto used for inferring the age of the

[1] See American Geologist: Russell, Vol. 3, p. 181, and Vol. 7, pp. 238–241; Hitchcock, Vol. 5, p. 201.

beds appear to have come from a single one of those subdivisions, one quite above the rocks of Newark, and the same that contains the Richmond coal. That coal, Gilbert says, does not occur in New Jersey, meaning, perhaps, not in large deposits like the Virginian; but yet no doubt it occurs there in thin layers and traces, just as in Pennsylvania, since the same subdivision of rock beds does extend into New Jersey. It is, perhaps, uncertain whether the Newark rocks, with their two reported fossil species, belong even to the Mesozoic.

There is in eastern Pennsylvania and New Jersey great unconformity at the top and bottom of the rocks in question; but it is not yet so certain that beds of the same age as the lowest of them do not occur conformable to Paleozoic beds in western Pennsylvania and elsewhere in eastern America, to say nothing of the West.

Clearly no claim for unity in the supposed group could be based on geographical continuity.

Would it not, indeed, be still more reasonable if he maintained that the Paleozoic rocks of the Appalachian region were a stratigraphic integer or unit, and consequently deserved a separate name?

2. There are, in truth, strong arguments in favor of generally giving local geographical names to stratigraphical groups, whether large or small. Yet there are many names of a different character that have had merit enough to become universally accepted, such as Paleozoic, Mesozoic, the Old and New Red Sandstones, Trias, Oolite, Calciferous, Corniferous, Saliferous, Carboniferous, Coal Measures, Millstone grit, Cretaceous chalk, Eocene and the like. Of course, the larger the group, the less easy to find a suitable, well-characterizing local name, the name of a place or region where the beds have been particularly studied, or much seen of men, or, as a whole, finely displayed; and that would be a difficulty with so extensive a set of beds as the one in question.

3. Gilbert, while insisting that Newark is the proper term in the present case, evidently admits that some such geographical

names are more suitable than others, requiring at least definite association with the rock beds, freedom from preoccupation, and priority.

The definite association he requires seems to be very slight; namely, the occurrence at Newark of perhaps one-tenth or one-twentieth of the beds to be included in the name, and with only two determined fossil species, plants. Suppose, in rummaging among old periodicals of forty years ago, a foot-note by some Baltimore collector were found, suggesting, without any attempt at either stratigraphic or geographical delimitation, that the whole body of Appalachian Paleozoic rocks be called the Cockeysville group, because, forsooth, the Paleozoic marble quarries there supply the city with fine building material; would not the argument for the revival of the name be quite as strong as in the almost precisely parallel case of Newark?

As to priority, and even preoccupation, and suitableness, too, is it not with geologists the same as with everybody else, that words, after all, are only used for the sake of being understood, and those words are to be used that will be most readily understood, so that currency, usage, is really the main criterion?

—Usus
Quem penes arbitrium est et jus et norma loquendi.

It is a great fundamental principle, that with the lapse of thousands of years has become more and more firmly established.

The rule of priority is an excellent one for cases otherwise doubtful or indifferent; but surely we should not be sticklers for it to the extent of raking up a name like Newark, that was unsuitable in the beginning, never did find acceptance, and was long ago wholly obsolete.

BENJAMIN SMITH LYMAN.

PHILADELPHIA, December 11, 1893.

AN ABANDONED PLEISTOCENE RIVER CHANNEL IN EASTERN INDIANA.

Rush and Decatur counties in southeastern Indiana are at present drained by Flat Rock creek and Clifty creek. The former has its source in Henry and the latter in Decatur county. Both flow in the same general southwesterly direction, and occupy deep channels which they have eroded in the hard and homogeneous limestone of the Niagara age. They discharge their waters into the east fork of the White river, the Flat Rock above the City of Columbus and the Clifty below. During one of the later stages of the Pleistocene period, and perhaps extending into the recent period, these counties were drained by a stream whose channel had a width of forty rods and a depth of ten or twelve feet, as shown by its well-marked banks composed of coarse river gravel. The elevation of the upper part of this stream was thirty feet above that of the rock bed of the recent streams. It had a more southerly course than these, having its point of departure from the present Flat Rock creek near Rushville, and its point of union with the present Clifty creek near Milford. As indicated by the map, the river may be described in four sections.

I. From a point about three miles above Moscow P.O., the old channel, called in this region "Hurricane," may be traced in a southerly course midway between the Flat Rock creek and the Little Flat Rock creek until it encounters the latter near the county line where the latter's course is westerly. Throughout this stretch the old channel has an elevation considerably higher than the modern streams. Comparatively little water now runs through this channel except in flood time.

II. From the point where the old channel encounters the present Little Flat Rock creek to a point about a mile below

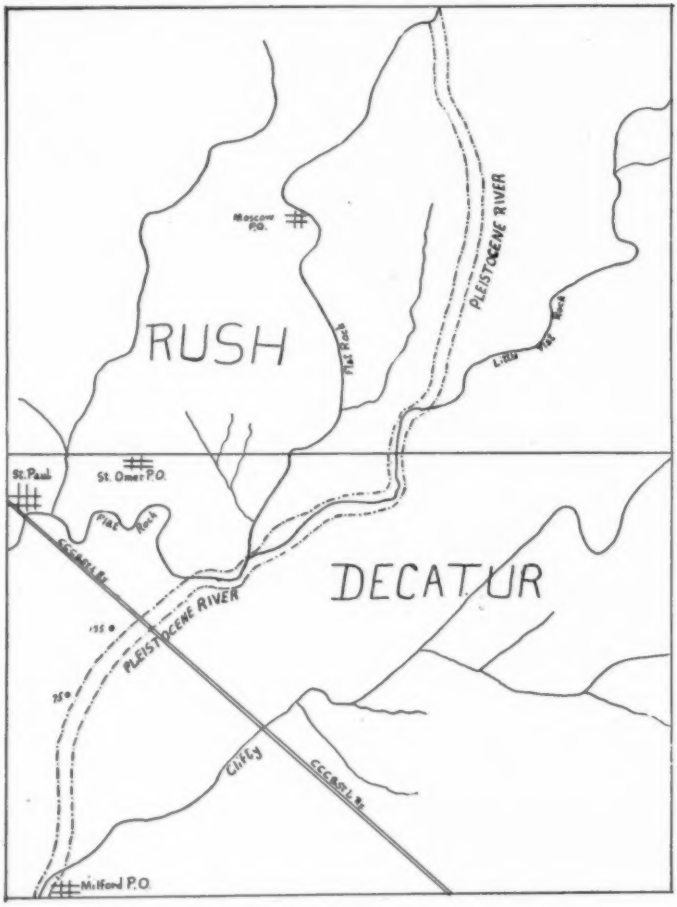
the junction of the Little Flat Rock creek with the Flat Rock creek, the old and the new channels approximately coincide. The old channel has been modified and lowered to about the level of that of the present streams.

III. The old channel departs from the recent channel at the point last described, and may be traced a little west of south to Milford P.O. It is about thirty feet above the recent channel of the Flat Rock creek at the point of departure, and has but a slight fall. The Flat Rock creek, in cutting its channel toward the north from the point where it left this ancient river, has carried away its water supply, leaving the abandoned part of the old river a relatively high marshy region known to the early settlers as "Beaver Pond." Recently an open ditch has been cut through it converting it into fertile corn and wheat land.

IV. From Milford the present Clifty creek flows through the old channel and has modified it, as in the case of the Little Flat Rock creek above mentioned.

If the Flat Rock and the Little Flat Rock creeks existed contemporaneously with the old stream they, as well as Clifty creek, were tributaries to it at the points named as their confluence, and doubtless flowed at the same relative level and had a less rapid fall than now. The evidence collected in regard to the bed of the old stream shows that it ran over the Niagara limestone in the upper part of its course with the exception of the region between the Flat Rock creek and Clifty creek (Section III.), where it flowed over Pleistocene deposits of considerable depth as shown by well sections. One of these, just below the C. C. C. & St. L. Ry. (see map), penetrated sand, clay, and bowlder clay to a depth of 135 feet without reaching rock. Another, a short distance below, is seventy-five feet deep in similar deposits without reaching their bottom.

The facts so far observed do not show precisely when the stream originated nor exactly how long it continued before its waters were diverted into their present courses. It seems probable, however, that it originated immediately after the retreat of the ice from the region, and was a part of the first definite system



Pleistocene River in Eastern Indiana -Beachler

Scale — one mile

of drainage that developed after the ice melted away. This would make it originate in the closing stages of the Pleistocene period. From the fact that the present Flat Rock has cut its channel in limestone about sixty feet at St. Paul below the bottom of the old channel, it would appear that it had been essentially abandoned a considerable time ago. Why the Flat Rock abandoned it at Moscow, and again south of St. Omer P.O., after it had reunited with it, I am not prepared to say. Nor can I say that it may not possibly have been a subglacial channel that was abandoned as soon as the ice melted away and left its waters free to follow the lowest depression of the surface.

The existence of the old channel north of the Little Flat Rock creek was first pointed out, so far as I know, by Dr. Frank Howard, of St. Paul, Indiana, who also assisted the writer in tracing out the channel for the purpose of preparing the map.

CHARLES S. BEACHLER.

STUDIES FOR STUDENTS.

PHYSICAL GEOGRAPHY IN THE UNIVERSITY.[1]

The logical method in geography.—Success in the study of geography, as in other subjects, depends largely on the share of mental light with which the facts are illuminated. For example, during the two weeks in which my class in physical geography has recently been occupied with the tides, a long roll of tracing linen has been hanging on the laboratory wall, containing copies of a half month of tidal curves at Honolulu, Boston, Philadelphia, Port Townsend (Oregon), and Point Clear, on the Gulf of Mexico. The essential facts of tidal oscillation are thus exhibited with great clearness, thanks to the kindness of Mr. Christie, of the U. S. Coast Survey, by whom the original records were selected, and under whose direction the copies were made for me. While these curves were illuminated only by the light that came in through the laboratory windows, the facts were but imperfectly perceived. The more peculiar variations of the curves involved in the diurnal inequality of tidal amplitude and interval could not be discovered by eyesight alone, at least

[1] NOTE.—Although it was the author's intention to prepare this essay for publication as one of the "Studies for Students" of this Journal, it has been unconsciously addressed as much to teachers as to scholars. This is perhaps excusable because of the little attention generally paid to physical geography in our colleges. The chief object of the essay is to present the plan of the author's course in this subject, with the hope that it may be tried by others, and modified or extended as experience shall advise. It may be added that a selected list of our governmental maps of use in teaching has been prepared by a sub-committee of the Conference on Geography of the National Educational Association, and that its publication may be expected at an early date; that a list of grouped sheets of foreign topographical surveys, with descriptive notes, is in preparation by the author, and that a list of selected photographs and lantern slides is in contemplation. With these aids it will be easier than it now is to experiment on systematic geography in the universities. W. M. D.

not by the simple eyesight of such observers as are found among average college students. But during the same week that the class was examining these tidal tracings in the laboratory, and thereby gaining an approach to a simple inductive knowledge of the principal facts of the subject, the problem was taken up from the other side in lectures, which discussed the theoretical consequences of the interaction of two bodies, and deduced from the theory of gravitation a number of special results that ought to occur if the theory of the tides is correct. As an aid in this deductive discussion, I placed three great circles of paper around a globe, so as to represent the theoretical arrangement of the tidal equator, and high tide circle and the low tide circle, and their relations to the latitude circles of the earth. Now, returning to the tidal diagrams with the results of the tidal theory in mind, it is only the poorly trained, the dull, or the stolid "student" who feels no mental satisfaction in the successful meeting of the facts of observation and the consequences of theory. Facts before noted, but not understood, now gain meaning; facts before disconnected now fall into their natural relationships; facts before unnoticed are now searched for and found, and wonder is even excited that they were not seen sooner. Neither induction nor deduction alone satisfies the mind. However full the series of facts, however extended the deductions from theory, both facts and deductions are of small value while they remain unmated. Properly confronted, they pair off and each one reacts on its mate most favorably. If the facts are well observed and recorded, if the theory is justly based and logically extended to its consequences, the inductions and deductions mutually complete each other, and the mind is satisfied. The window light then seems a dull illumination of the tidal tracings compared to the light that shines on them from the understanding.

As with the tides of the ocean, so with the forms of the land. They are but half seen if examined only by daylight. They are less than half appreciated if seen without an understanding of

the generalizations by which they are correlated. The more complete the mental scheme by which an ideal system of topography forms is rationally explained, the more clearly can the physical eye perceive the actual features of the land surface; the more definitely can it record them in mental impressions. Topographical forms are so varied, and often so complicated, that the outer eye alone is no more competent to detect all their intricacies and correlations than to discover all the peculiarities of the tidal curves. It is true that with exceptionally keen powers of observation, and with unusual opportunity for deliberate examination, the unaided eye may come to see more and more of the ultimate facts; but these conditions are so rare that they need not be considered. The average eye, and the usual time allowed for observation do not suffice; they must be supplemented by the quickened insight that comes from rational understanding.

No better confirmation of this conclusion can be found than in the experience of those who have to employ engineers, untrained in geology and geography, to make topographical maps. The work that such surveyors produce is rigid, mechanical, unsympathetic, inaccurate, inexpressive. If time were allowed them to run out all their contours by actual measurement, an exact map might be produced; but neither time nor money can be devoted to so slow and expensive a method. Even the best surveys are necessarily sketched in great part; and the topographer must appreciate his subject before he can sketch it. He must have a clear insight into its expression; his outer eye must be supplemented by his inner eye. Then he can make up a valuable, even though not an expensive, map. I do not mean for a moment that he is to invent and not to observe; that he is to make a fancy picture instead of a true likeness. My point is simply that the difficulty of making a true likeness is so great that all aids towards it must be employed; and one of the chief aids to sharp outsight is clear insight. How can a clear geographical insight be gained?

An analogy with the study of the tides may still serve us. The facts of the tides are first presented in what seems like a

bewildering, even an overwhelming, variety, without suggestion of order or meaning. While these facts are studied and classified, let the system of the tides be deduced in accordance with accepted physical laws. Let the tidal theory be followed far enough to discover consequences so numerous and so intricate that they cannot be imitated by chance. Neither the inductive nor the deductive work should have precedence. They should advance together, but without confusing one with the other. When both processes are well advanced, let the facts be reëxamined in the light of the theory, and summon a critical judgment to determine how far the reports of outsight and insight agree. Success in such study requires that the facts shall have been closely observed, clearly described, and fairly generalized; the inductive results thus gained being held apart by themselves. It requires, also, that the theory shall have been logically extended to its legitimate consequences; the deductive results thus secured being stored away in a special mental compartment. Then, in due order, bring forth the corresponding members of the two classes of results, and judge of the success of the theory by the agreements thus discovered.

Let the same method be applied in the study of geography. Set an abundant array of facts before the class in the laboratory. Let the facts be examined and classified as far as possible, simply according to their apparent features and without regard to explanation. At the same time, present an outline of a deductive geographical system in the lecture room. During the advance of the two lines of work, compare their results frequently, but do not confuse them. In a few months a large array of facts may be examined, an extended deductive system may be developed, and the two may be compared in the most thorough manner. Every comparison aids further advance in both parts of the work. Both outsight and insight are cultivated. A geographical understanding, based on a proper combination of many mental faculties, is aroused and strengthened. The real study of geography is well begun. The several steps involved in this plan of work may now be traced in some detail.

Introductory illustration of facts.—It is well at the outset to present a collection of varied geographical illustrations, in order to bring prominently before the mind the great variety of the facts with which we have to deal. At the same time, a preliminary exercise is gained in the interpretation of different means of geographical representation. The following list will serve to indicate the class of materials from which selection may be made for a first week's laboratory work:

Heim's model of an Alpine torrent; Harden's model of Morrison's Cove, Penn., or a photograph of this model, or of Branner's model of Arkansas; Jackson's photograph of the deep valley of the Blackwater in the plateau of West Virginia; Hölzel's oleograph of the Hungarian plain; Becker's elaborately colored and shaded relief map of the Canton Glarus, Switzerland; a group of contoured map sheets, as the twelve that embrace the Berkshire plateau and the Connecticut valley in western Massachusetts, mounted as a wall map for better convenience in study; a hachured map, such as that of the Scotch Highlands, in a group of sheets of the British Ordnance Survey, also mounted as a wall map; a tinted relief map, as of New Jersey, from the topographical atlas of that state, etc., etc.

The need of the systematic study of geography is apparent from the difficulty that most students have in expressing the facts portrayed in these various illustrations. Words are not easily summoned to describe them. Many of the illustrations are on a much larger scale than is commonly employed in atlases, and the ordinary accounts of direction and distance usually employed in describing similar maps, are at once felt to be insufficient to express the varied reliefs here exhibited. How can the student best approach a perception and an understanding of the facts before him and at the same time gain an ability to describe them in fitting language?

Insufficience of inductive study.—The ordinary fund of geographical terms does not suffice to describe good maps and models with sufficient exactness. Further than this, a few questions from the instructor will show that many facts plainly set forth

are not seen at all. Interpretations and correlations are not even suspected. This is perfectly natural when it is remembered that most college students have never been taught to observe closely or to express themselves clearly in well chosen words. It is still more natural when it is remembered that the little knowledge of geography that they have brought from school is hardly more than a confused memory of an unsystematic, empirical text book. Whether their observation is directed to the semblance of facts in maps, views, and models, or to the actual facts of outdoor nature, observation is attempted only with the outer eye; the inner eye has never been opened. The idea that all the forms of the land are systematically developed has never been implanted in their minds. They possess no general and well tested deductive understanding of the development of land forms, no system of terrestrial morphology. The facts of observation excite no harmonious response from the corresponding members of a deductive geographical scheme.

While the study of geography remains in this incomplete and illogical condition, it is a blind study, although it is carried on chiefly through the eye. While the life of the features of the earth's surface is not perceived, geography is a dead study. The features of the land that the outer eye sees will awaken no sufficient sympathy in the understanding until the scientific imagination has deduced a whole system of geography, filled with mental pictures of all kinds of forms in all stages of development, among which the report from the outer eye may find its mate. However faithfully mere observation is carried on, the impression on the retina might as well be the record on a photographic plate, as far as appreciative insight and understanding are concerned. Let us therefore strive to complete a deductive geographical scheme, even as we strive to complete our deductive tidal scheme, until it shall at last be ready to meet not only all the actual variety of nature, but all the possible variety of nature. Only when such a scheme as this is well advanced is the student ready to appreciate the materials presented in the laboratory work. The maps and models shown in the first week

are therefore repeatedly introduced with others in the systematic advance of the course; and the student may gauge his progress by the increased meaning that these illustrations gain on every return.

Let us next consider the development of a deductive geographical scheme, by which external observation is to be supplemented and completed. Let it be understood at the outset that to exceed the variety of nature is an extended enterprise, a remote and ideal goal, towards which we strive. Let no excessive flight of theory carry us far from the earth and overcome us in mid-air. Let us carefully guard against an unwarranted wandering of the imagination by frequent conferences with the facts of observation, hoping to return, like old Antæus, strengthened for new efforts after every touch of Mother Earth.

The deductive geographical scheme.—It is the fundamental generalization of elementary geology to note that the lands are wasting away under the destructive attack of the weather. The hardest rocks decay; their waste creeps and washes down to lower and lower levels, never satisfied till it reaches the sea. However broad a plateau, however lofty a mountain range, it must, if time enough be allowed, be worn down to sea level under the weather; and the unceasing beat of the sea on its shores must reduce it still lower to a submarine platform. Since the remote beginning of geological time there has been time enough and plenty to spare to reduce all the lands to such a submarine platform; but as high lands still exist, it must be concluded that they are revived from time to time and from place to place by some forces antagonistic to those of subaërial denudation. In whatever way a new mass is offered to the wasting forces, let us call the forces that uplift it constructional forces; and the forms thus given, constructional forms. Let all the forces of wasting be called destructional forces; let the sea level surface, down to which a sufficiently long attack of the destructional forces will reduce any constructional form, be called the ultimate baselevel; and let the portion of geological time required for the accomplishment of this task be called a geo-

graphical cycle. Construction, destruction, baselevel and cycle are our primary terms. A full understanding of the destructional processes requires deliberate study of mineralogy and lithology, chemistry and structural geology; a good understanding of constructional forces and processes has not yet been gained, but a review of the advance made towards it carries the student through a wide range of geological theories, in which physics and mathematics are continually appealed to—perhaps sometimes with too great a confidence in the applicability of their conclusions concerning an ideal earth to the case of the actual earth.

If the cycle of destructive development is not interrupted, any constructional form will ultimately be reduced to a monotonous baselevel plain of denudation. This is a broad abstract statement. It is simply the first framework of the geographical scheme. It is a mere sketch in faint outline, needing all manner of finishing before its full meaning can be made out. It must be filled in by the gradual addition of details. The first step involves the recognition of the systematic sequence of topographic forms produced during the accomplishment of the destructive work. This should be considered before classifying the various kinds of constructional forms on which the destructional processes begin their tasks. Whatever constructional form exists at the beginning of the cycle, there is a certain general succession of features common to nearly all cases of geographical development. The understanding of this succession calls for the study of river systems and the general drainage of the land under their guidance; because it is so largely under the control of these processes that the destructive forces do their work.

Constructional drainage.—At the beginning of a cycle, there are relatively broad, massive forms, on which the carving of the destructive forces has made no mark. The unconcentrated drainage, or wet-weather wash, takes its way down the steepest slopes of the constructional surface, until the supplies from either side meet obliquely in the trough lines, forming constructional

streams; these unite, forming constructional drainage systems. If the trough lines are systematically arranged, as among the corrugations of mountain folds, the initial drainage system is definitely located; if the trough lines are faintly marked and lead irregularly about, as on the nearly level surface of a plateau, the drainage is essentially vague and unsystematic. If the general descent of the trough lines is here and there reversed into ascent, lakes are accumulated in the basins thus determined; and this is very common. If the descent of the trough lines is locally intensified, constructional falls or rapids are developed, but this is relatively rare.

Consequent drainage.—The constructional streams run down their troughs, carrying along the waste that is washed into them, and trenching channels beneath the initial constructional surface; or filling constructional hollows; that is, degrading or aggrading their course, as the necessities demand. As soon as they thus depart from their initial constructional arrangement, they may be called consequent streams. It is true that the constructional phase of a drainage system endures only a moment; yet it seems advisable to recognize this phase by employing a special name for it, before introducing the term, consequent, which indicates the much longer phase that next follows. At least, I am for the present experimenting on these two terms with my classes, and find them of value. As long as a stream flows on a line that is essentially the perpetuation of its original constructional course, it may be called a consequent stream; the trench that it cuts and the valley that is formed by the widening of the trench may be included under the name, consequent valley. Constructional features are encroached upon as the consequent features make their appearance. A constructional lake decreases in size by filling at the inlet and cutting down at the outlet; while thus dwindling away, it is a consequent lake. A fall or cascade recedes from its initial constructional position; but as long as it endures it is a consequent fall.

Subsequent drainage features.—As the consequent streams

deepen their valleys beneath the constructional surface, it often happens that they discover structures of unequal hardness. If, in passing down stream, a weak structure succeeds a hard structure, the valley will be quickly deepened in the former and slowly in the latter; a local increase of slope appears and a fall or cascade is the result. This is a subsequent fall on a consequent stream. It endures until the harder structure is worn down or back so far that it overtakes the deepening of the stream bed below the fall. The extinction of falls is accomplished in adolescence on large streams and on tilted rocks; but it may not be reached until maturity on the smaller streams in regions of horizontal strata.

A further consequence of the discovery of the variable resistance of internal structure is the variable rate at which the narrow young consequent valley widens into the more mature open valley. If the consequent stream crosses a local transverse belt of hard rocks, the gorge-like form of the valley walls may there be retained into the maturity of the region as a whole. If it crosses a belt of weak rocks, the consequent valley may there widen so greatly as to develop other valleys on either side of its path. Thus many a transverse consequent stream, cutting its valleys across belts of harder and softer structures, allows the development of longitudinal valleys on every belt of weak structure that it traverses, while the intermediate belts of harder structure stand up as longitudinal dividing ridges. The longitudinal streams and valleys are then called subsequent branches of the transverse consequent streams and valleys. Each of the subsequent streams deepens its valley only as fast as the down-stream deepening of the consequent valley permits.

It is extremely important to recognize the difference thus indicated between consequent and subsequent streams. The first control the drainage of a region in its early stages of development. The second are of increasing importance in the secondary and later stages of growth, when they share the drainage of the region with the surviving consequent streams. Subsequent falls

frequently appear on consequent streams, but they are rare on subsequent streams.

It is manifest that the development of subsequent streams will progress to the greatest extent in regions of disordered and complicated structure, in which the attitude of the rocks is varied, and in which contrasts of hardness are well marked. Such is the case in mountainous regions. On the other hand, regions of horizontal structure have no normal subsequent streams. All the branch streams are either perpetuated constant streams, or else they are developed under accidental controls, of which no definite account can be given. It is to these self-guided streams that McGee applies the term, autogenetic.

Divides.—The constructional divides waste slowly and become consequent divides. They are well defined in a region of distinct constructional relief; they are vague or practically absent on the even surface of young plains, where the drainage areas are really undivided. As subsequent streams develop, especially in regions of tilted structure, they frequently split a consequent divide, and make two subsequent divides between which lies the growing subsequent valley. As the subsequent divides are split further and further apart, lateral subsequent streams are developed down the internal slopes of the subsequent valley; and these are in headwater opposition to the lateral streams on the diminishing slopes of the adjacent consequent valleys. During changes thus produced in the position of divides, they migrate by slow creeping as long as the competing streams are in headwater opposition; but if, as sometimes happens, the head of an encroaching subsequent stream pushes its divide back until it cuts into the side of a consequent stream, then the divide leaps around the consequent headwaters above the point of capture, and a considerable area that had been tributary to the captured stream is suddenly transferred to the capturing stream.

A limit of these re-arrangements is gradually approached. The persistent consequent streams and the successful subsequent streams come to an understanding about their drainage areas. The divides as well as the streams are then maturely adjusted to

the structures on which they are developed; and thenceforward further change is slow.

Stream profiles.—Let us next examine the changes produced in the initial profile of the troughs where the first constructional streams settled. The irregularities of constructional profile which determine lakes and falls are in most cases soon extinguished. The profile of a consequent stream may for a time possess unequal slopes at its subsequent falls, but it soon attain a tolerably systematic curve of descent, steeper near the headwaters, flatter near the mouth. While the young stream has abundant fall and rapid current, with moderate load delivered from the relatively simple constructional and consequent slopes of its basin, it deepens its trench rapidly. But as the profile becomes flatter and the current runs slower, and as the area of wasting slopes increases by the deepening of the consequent valleys and the development of subsequent valleys, a time will soon arrive when the carrying power is reduced to equality with the load; and from this time on the deepening of the valley is very much slower than before. It is only as the load from the wasting slopes decreases in amount that the deepening can go on. Following certain French writers, the profile of the stream when this balanced condition is reached has been called the *profile of equilibrium.* The term is inconveniently long; but the idea is of essential importance. Mr. Gilbert has recently suggested to me that a stream in this condition of balance between degrading and aggrading might be called a graded stream; and its slope, a graded slope.

It is sometimes said that streams in this condition have reached baselevel; but this introduces a confusion of ideas that should be avoided. For example: given two constructional areas of similar form and altitude, and under equivalent climatic conditions; but let one be made of resistant rocks, and the other of weak rocks. The baselevel is the same for both. The streams will cut deep into the harder mass, producing strong relief before reaching an equilibrium profile; because its waste is shed so slowly that the streams can carry it on a faint slope.

They can cut only shallow valleys in the weaker mass, for its waste will be shed so rapidly that a steep slope is needed by the streams to carry the waste away. The contrast between the two areas is strengthened if the region of harder structure has a plentiful rainfall, and the region of weaker structure has a light rainfall. All of these points of difference are with difficulty stated, if the streams are said to have reached baselevel when their carrying power is reduced to equality with their load.

In certain cases, it seems to be possible for a stream to cut down its profile to a gentler grade in its early adolescence than is suitable to later adolescence and maturity. If we conceive that the load offered by the waste from the valley slopes continues to increase after the grading of the stream has been reached, then the grade must be steepened again by the deposition of the excess of load; thus increasing carrying power and decreasing load, and maintaining an equilibrium. Local examples of this relation are often seen in valleys among mountains, where a lateral stream is depositing an alluvial fan in the larger valley that it enters. The larger valley was deepened before the lateral valley had gained a considerable area of wasting slopes; but as the lateral valley grows headwards and discharges an increasing volume of waste, it cannot all be carried by the main stream, and hence the main valley is clogged up, and its grade is somewhat increased.

Stages in the cycle of geographic development.—Following the terminology of organic growth, it is convenient to speak of the successive stages in the geographical cycle as infancy, youth, adolescence, maturity, old age, and perhaps second childhood. Let us consider particularly the activities of the drainage system as determined by the topographic form of a region in its different stages.

In infancy, the rainfall is slowly concentrated from the broad constructional surface; it is only gradually collected into streams; it is often delayed in lakes. Much of it is lost by evaporation, and the ratio of discharge at the river mouth to rainfall over the river basin is relatively low. The initial streams simply adopt the courses offered to them, without the least consideration or

foresight regarding the difficulties that these courses may involve in the process of valley-trenching. The load that they have to carry is relatively light; being only the waste that creeps and washes down the broad constructional slopes, under the guidance of the unconcentrated drainage.

In youth and adolescence, the drainage lines are increased in number and greatly improved in their ability to gather and discharge the rainfall quickly. Numerous little trenches are incised in the broad constructional surface, and the distance that the land waste washes and creeps under the guidance of unconcentrated drainage is much lessened; delay in lakes is decreased; the steep lateral slopes of the young consequent valleys furnish an increasing amount of load to the streams, although they still as a rule have carrying power to spare in their impetuous currents. A good beginning is made in the search for the best location of subsequent streams. As the subsequent streams are better developed in later adolesence, the original broad constructional forms are minutely carved, many subsequent divides are established, the discharge of rainfall is very prompt, and the load of waste that the streams have to carry is notably increased.

In maturity the relief retains much of the intensity of adolescence, and adds thereto a great variety of features. The valley lines are closely adjusted to the structure of the region, this condition having been gained by a delicate and thorough process of natural selection, in which the most suitable drainage lines survive, and the less suitable ones are shortened or extinguished. The impetuosity of youth has disappeared; all the larger streams have developed grades on which their ability to do work is nicely adjusted to the work that they have to do; the lower courses already show signs of age, while the upper twig-like branches are relatively youthful. The whole drainage system is earnestly at work in its task of baseleveling the region, and the forms that the region has assumed bear witness to the close search made by the streams for every available line of effective work.

From this time onward, there is a general fading away of strength and variety, both of forms and activities. The deepen-

ing of the valleys progresses even slower than the slow wasting away of the hill tops; the relief fades; the load offered to the streams lessens. The rainfall slowly decreases as a normal consequence of decrease of altitude; the ratio of river discharge to rainfall decreases; the small headwater branches shorten and dwindle away; the close adjustment of stream to structure is more or less lost, especially by the larger rivers, which meander and wander somewhat freely over the peneplain of denudation. Extreme old age or second childhood is, like first childhood, characterized by imperfect work; activities that were undeveloped in the earlier stage having been lost in the later stage.

All this should be so carefully imagined and so frequently reviewed that the orderly sequence of changes may pass easily before the mind. The mind should come to be in so close a sympathy with the progress of the cycle as to forget human measures of time and catch instead the rhythm of geographical development; even to the point of almost wishing to hurry to one place or another where some change of drainage or of form is imminent, for fear of failing to be in time to see it in its present stage.

Shore lines.—While the subaërial forces are denuding the surface of the land, the waves are beating on the shore and reducing the land mass to a submarine platform. They begin their work on a level line, contouring around the slope of the land mass as it is offered to them. The contour is simple if the sea lies on a rising sea bottom, evenly spread over with sedimentary deposits; the contour is irregular if the sea lies on a depressed land, more or less roughened by previous denudation. The waves of a great ocean work rapidly on a leeward shore, especially if it has a steep slope and if its rocks are not too hard: but if the descent to deeper water is very gradual, the waves may for a time spend their force chiefly on the bottom, building off-shore bars with the material they gather up, and thus deepening the water outside of the bars for a better attack on the land later on. The shore line is generally simplified, as the attack advances, but it may for a time become more irregular if the waves are strong and the land structure is of diverse resistances. Its changes deserve as care-

ful an analysis as is given to the forms of the land; but they cannot be traced here for lack of space.

Illustrations of the deductive scheme.—However much the advance of a deductive scheme of study may be aided by reference to concrete illustrations during its progress, its statement should be abstract, in order to emphasize the essentially deductive side of the study. It is difficult to follow such a method without artificial aids. Hence, in discussing the theory of the tides, a model of certain theoretical tidal circles was introduced for the convenience of definition and argument. It was found to be an effective aid in reaching certain geometrical consequences that follow from the rotation of the earth on an axis that is not coincident with the axis of the tidal circles. This model was an illustration of the same order as the diagrams employed in text-books on geometry. In the same way, a series of some thirty rough paper reliefs, constructed several years ago to illustrate a course of lectures to teachers under the auspices of the Boston Society of Natural History, are introduced to aid in giving clearness to the conception of the geographical scheme. They are roughly made; hardly better than blackboard diagrams, except in having three dimensions; yet they certainly serve a good purpose as aids in following deductive statements. Being two or three feet in length and yet light enough to handle easily, they are frequently brought into the lecture room, although they are used chiefly in the laboratory, where they can be examined and described deliberately. Nearly all the points thus far mentioned are illustrated in one way or another by these models; but I can here give account of only a few of them.

While occupied with the first considerations of the cycle and its systematic variations of relief, both in intensity and variety, use is made of three simple models, which are found to be of particular value in fixing the fundamental ideas. The first shows a broad upland, traversed by a main river with a few branching streams, all in valleys of the canyon type. The form of the second is well diversified, there being about as much of lowland in its wide open valleys as there is of upland on its well separated

hills. The third is a broad lowland for the most part; but low hills rise above the general level near the headwaters of the streams. The main river has essentially the same course in all three models and there is a manifest relation in the position of the streams and interstream hills of the series, plainly showing genetic relationship. The three models are different forms of the same region at certain stages in its cycle of development. Exercises are held in the simple description of these forms, and of other forms that might be interpolated in the series. It is suggested that the duration of a cycle should be divided into a hundred equal parts, and that the stages occupied by the three models should be designated by appropriate numbers. After some discussion, it is agreed that they may be represented by five, twenty and forty; thus impressing the idea that maturity is reached long before middle life; and that the passage through old age is extremely slow compared to the advance from youth well into maturity. These exercises are accompanied by others in which illustrations of actual geographical forms are presented, as will be explained later; but it is important that the different character of the two should be clearly kept before the mind.

Complications of the simple scheme.—The difficulty of finding examples of actual forms in the various stages of development of a single cycle suggests that the departures from the ideal uninterrupted cycle should be examined. These are of two kinds, which I am accustomed to call accidents and interruptions. Such departures as do not involve a change in the attitude of a land mass with respect to its baselevel may be classed under the first heading as accidents; those which do involve a change with respect to baselevel will fall under the second heading of interruptions.

The most important accidents are climatic and volcanic. Climatic accidents include changes from humid to arid, and from cooler to warmer conditions, independent of the normal climatic change due to loss of relief from youth to old age. A study of such a region as the Great Salt Lake basin, or as the glaciated

district of northeastern America assures us that these accidents may succeed each other rapidly; very rapidly compared to the rate of normal climatic change dependent on loss of relief from a constructional beginning to a destructional end. Volcanic accidents include the building of cones and the outpouring of lava flows. Both the glacial and the volcanic accidents may occur at any stage of a cycle. They both in a way involve constructional processes; both may be regarded as furnishing examples of new constructional forms; but when looked at with respect to the surface on which these accidents are imposed, and with respect to the relatively brief endurance of the effects of the accidents, they are seen in their relatively subordinate character. When sheets of drift are heavily spread over a country of low relief, or when heavy lava floods cover and bury some antecedent topography, the accidents assume such proportions that they may be considered as revolutions, after which a new start is made in the processes of denudation.

A cycle is interrupted when the land mass rises or sinks, or when it is warped, twisted, or broken. Like accidents, interruptions may happen at any stage of development. It is then convenient to say that the destructional form attained in the first incomplete cycle shall be called the constructional form of the new cycle, into which the region enters, more or less tilted or deformed from its former shape. Assuming for the moment that the constructional process is so rapid that its duration may be neglected, it follows that in cases of simple vertical movement, up or down, the rivers and streams at once proceed to adapt their activities to the new conditions. They are shortened and betrunked, if the interruption is a depression; they are revived and extended if the interruption is an elevation. These two special conditions are illustrated by paper models. One model exhibits a rolling country, into which a branching bay enters; a stream descending into the head of every branch of the bay. No flats occur at the head of the bays; no cliffs are seen on the headlands. Hence it is said, that on reaching maturity this country was depressed, and that the depression occurred very recently.

The numerical expression of this example would be 20, —, 0: the minus sign not indicating subtraction, but merely signifying depression; and the zero indicating that no advance has been yet made in the new cyle. Another model exhibits a broad, gently undulating upland, traversed by a very narrow canyon. This is interpreted to signify that an elevation occurred in the old age of the region, and that since then the streams have simply entered a new youth, incising young valleys in the uplifted peneplain. The formula of this example would be 60, +, 3. Examples involving deformation of a land surface, and the accompanying possibility of antecedent streams, are more complicated, and cannot be here introduced.

It is convenient to use the term, episode, for slight interruptions, so as to express their relative unimportance. I have also attempted the use of the term, chapter, for an unfinished cycle; but in talking with students this specialization of terms hardly seems necessary. Any region whose surface has been developed, partly with relation to one baselevel, and partly in relation to another; that is, any form whose development has involved two or more incomplete cycles, is said to have a composite topography. Many examples of such forms are encountered.

Special features of second or later cycles.—It is interesting to notice that, in certain cases, the adolescent stages of a second or later cycle, following the elevation of a region well advanced in a previous cycle, present features that did not characterize its first adolescence. One case of this kind is seen in meandering river gorges. Young rivers in their first cycle may cut crooked gorges, but they then follow consequent courses, and these cannot manifest the close relation between volume and radius of curvature that is seen in true meanders. This relation is found only in oldish rivers, which develop systematic meanders on their own flood plains. But if the region on which these rivers flow is introduced into a new cycle by uniform elevation, the rivers may cut down their meandering channels and produce meandering gorges. The Osage in Mis-

souri,[1] and the north branch of the Susquehanna in Pennsylvania; the Seine in northwestern France, and the Moselle in western Germany, may be cited in illustration of this kind of occurrence.

Another case in which a second adolescence is unlike the first is found in regions of tilted structure, where the strata are of diverse resistance, thus giving good opportunity for the development of subsequent streams. In the beginning of the first cycle there are no subsequent streams. All the drainage is constructional (antecedent streams not being now considered). In adolescence, the drainage is chiefly consequent, although subsequent side streams are then beginning to bud forth from the consequent streams. In past-mature stages, the subsequent streams may have acquired a considerable part of the drainage area. Now, if a region of this kind, with consequent and subsequent drainage, is bodily elevated, all the streams are revived; they all cut down new trenches toward the new baselevel. But in this case the revived subsequent streams begin the new work at the same time as the revived consequent streams, and they will go on rapidly in acquiring still more drainage area. Therefore, in the adolescence or maturity of the second cycle, the drainage area acquired by the subsequent streams will be proportionately large; much larger than at the same stage of the first cycle. Much faith may be placed in this deduction. If the drainage of an adolescent region is largely subsequent, and but little consequent, the region may be regarded as almost certainly in a second cycle of development, after a first cycle of well-advanced age.

Illustrative material.—One of the greatest difficulties in the way of teaching physical geography arises from the failure of the student to know what the teacher is talking about. The teacher may have traveled and observed extensively; a large variety of geographical forms are in his memory, ready to be summoned by name when picturing the stages of the deductive

[1] It has been suggested to me by Mr. Arthur Winslow that the Osage has increased its original meanders in cutting down its gorge. The other rivers here mentioned seem to have done the same thing.

scheme; but no amount of description suffices to place these mental pictures before the class. The best means of overcoming this difficulty is found in the use of the projecting lantern; and now that the electric light may be used in projecting slides on the screen, and the room kept light enough for the class to take notes while the pictures are exhibited and explained, the only thing left to be desired is a good series of views, carefully selected to present typical examples of land forms in various stages of more or less complicated development. These views are not intended primarily to furnish localized examples of geographical forms; although, of course, they have much value in that direction. Their greater value comes from the vividness of the conceptions by which the different kinds of forms and different stages of development of the deductive scheme are held in the mind. The collection of slides that I now use includes a large variety of views; although very useful, it is still imperfect. It should be extended by the addition of many views taken expressly to meet its needs; for the photographs and slides commonly to be had of dealers are as a rule taken with anything but geographical intention. As an indication of the character of illustrations used in a single lecture, I may mention the following examples, and add an outline of the comments made on them.

When the general idea of a geographical cycle has been presented, including the constructional forms with which it begins, and an outline of the destructional forms by which its development is characterized, the next lecture may be devoted almost entirely to illustrations. First, a few slides to show various constructional forms. Muir's Butte, a young volcanic cone in California, introduces a series; it is practically unworn. Its growth was so rapid and so recent that no significant advance in its denudation has yet been accomplished. Mt. St. Elias comes second; as described by Russell, it is a constructional form slightly altered; an essentially young mountain mass. The considerable time required for accomplishment of so great a constructional work may have been enough for the slight dissec-

tion already seen on its surface. While the building of a volcanic cone is spasmodic, almost instantaneous, the uplift of a great mountain is rather slow; its uplift is brief only when compared to the duration of the destructive cycle on which it thereby enters. When first describing the cycle, it was implied that the destructive forces make no beginning until the constructional forces have completed their work. The view of St. Elias corrects that false idea. Several plains follow; all dead level; all ending in even sky lines. The Llano Estacado of Texas, the lava deserts of southern Idaho, the littoral plain of southern New Jersey, the lacustrine plain of the Red River of the North. The areas included in these views show no signs whatever of destructive processes; the surfaces are essentially as flat as when they were born. A pair of drumlins in Boston harbor, and a glacial sand-plain in Newtonville, Mass., as represented in a model by Mr. Gulliver,[1] introduce examples of peculiar constructional forms; and as the more intelligent members of the class soon point out, these might be as fairly included under a consideration of destructional processes as of constructional processes; for they really belong among the "forms taken by the waste of the land on its way to the sea," under certain special conditions, and they will be reviewed in a later chapter of the course under that heading. The drumlins and the sand-plain may also be regarded merely as evidence of a glacial accident during the denudation of the New England plateau.

Passing next to illustrations of young destructional forms, Mt. Shasta is exhibited, with great gulleys worn down its flanks. It is at once pointed out that these gulleys follow lines of constructional slope; that they began as the paths of constructional streams, defined by some accidental irregularity in the form of the volcanic cone; and that they are now slightly advanced in their consequent growth. The Mancos canyon in Colorado illustrates the beginning of the dissection of a plateau; the consequent stream having here cut down a steep-sided consequent valley, but apparently not having yet graded its slope. A

[1] See this Journal, Vol. I., p. 801.

stream in Florida, hardly incised in the low coastal plain, illustrates the faint relief permitted in surfaces that stand but little above their baselevel. The Colorado, in its canyon, is another example of an early stage of development, but it possesses an extreme intensity of relief because of the great altitude of its plateau; not an old valley, but a precocious young valley; not a vast work, except in our inappropriate human measures, but the good beginning of a vast work. The Elbe above Dresden offers illustration of a later stage than the three preceding; it has the beginnings of a flood plain, now on one side, now on the other side of the river; from which it is inferred that the deepening of the valley has practically ceased, that the river is graded, and that the slower process of valley widening is now the determining cause of topographic change.

Views in the Jura mountains would serve as examples of adolescent forms, combining an interesting measure of consequent and subsequent features; but I have not yet succeeded in finding any satisfactory photographs of this region. Features of maturity, more or less advanced, are found in the retreating escarpments of the middle Ohio valley[1] or of the central denuded region of Texas; and again in the minutely carved ranges of the central Alps. For yet older stages, it is difficult to find examples still in the cycle in which their old age was reached; but the plain of the middle Wisconsin river and the plateau of the middle Rhine are ideally satisfactory illustrations of baseleveled surfaces, one being an old plateau, and the other an old mountain region; although both have lately been brought into a new cycle by elevation, allowing their rivers to cut narrow trenches beneath their even surfaces. By selecting views in which only the plain surface is seen, these examples make appropriate closing members of the series here described. At a later time, when the complications of the cycle are in discussion, other views showing the dells of Wisconsin and the gorge of the Rhine may be presented, thus giving a new meaning to old examples.

[1] Not the slopes of the young trench by which the Ohio now cuts across the Cincinnati plain, but the escarpment enclosing the plain many miles back from the trench.

Systematic examination of facts.—While the deductive geographical scheme is thus gradually extended, while its various elements are illustrated more or less completely by blackboard diagrams, diagrammatic models, and lantern slides, an acquaintance with the facts of the subjects is gained at the same time chiefly through the laboratory work of the course. This is for the most part devoted to the examination of maps and many other illustrations of actual geographical forms, introduced systematically to represent the kinds of construction and the stages of development that may be compared with similar kinds and stages in the deductive scheme. I regard it as essential that the two sides of the work should advance together. The theoretical considerations of the deductive scheme and the inductive observation, description and generalization of the facts of nature continually react on each other to mutual advantage. They call different mental faculties into exercise. Neither one can be developed alone to the best advantage. It is true that the consideration of the two sides of the work at the same time leads to mental confusion on the part of untrained or careless students, but this does not seem to me unfortunate. It is, to be sure, rather disappointing for a young fellow to find in the middle of the course that his neglect of its beginning has left him hopelessly behind his better prepared or more persevering comrades; but it is much more disappointing to see how often collegiate instruction is degraded by allowing it to fall to the reach of students who do not know how or who do not care to know how to follow its proper quality. In work of the kind that I am describing, mental confusion soon overtakes those who are poorly trained for mental effort. I do not find that it makes much difference what subjects a student has been trained in, provided that he is well trained.

Laboratory work is an important element in the study, because there is otherwise no opportunity for deliberate and close observation of geographical facts. Even if shown in the lectures, they cannot be clearly seen, and there is no time then for close study. No text book or atlas contains illustrations in sufficient variety

for collegiate work. But in the laboratory, numerous maps, views, or models may be exposed on walls, racks, or tables, remaining for a week together, and thus giving abundant time for deliberate examination. From week to week a change may be made in the materials, the group for each week corresponding to the group of problems then in hand. Many of the illustrations shown in the first week are repeatedly brought forth again later in the course, always gaining new meaning as sharper outsight and insight are directed to them. Many facts of interest concerning population and occupations may be brought forward in this connection; but it is important that the geographical facts should first be clearly apprehended.

In the reports that are made on this laboratory work, the students first describe the facts that they have observed, in terms that have no suggestion of explanation. They should not say that a certain region is a baselevelled surface; but that it is a lowland of faint relief. They should not at first speak of old rivers revived into a second youth; but they may say that the rivers of a certain region run in deep, narrow valleys below an upland of generally uniform altitude, above which occasional isolated hills rise to greater elevations. This I regard as extremely important, in order to ensure a careful observation of the facts in discussion; for until the facts are clearly perceived they cannot be precisely explained. It is unsafe at first even to speak of the flat region at the mouth of a river as a delta. This term not only denotes the form of the surface but connotes an explanation; and in the earlier weeks of the study it is by no means sure that the observer fully perceives all the facts of form that are denoted by the term, or that he fully appreciates all the features of the process that are connoted in its explanation. The outbranching of the distributaries near the river mouth as contrasted with the inbranching of the tributaries (or contributaries, as they might be called), further up stream; and the faintly convex form of the delta surface as contrasted with the concave form of the upper valley may not be clearly observed, unless they are concisely formulated in a description. The essentially bal-

anced relations of carrying power and load involved in the explanation of the growth of delta may not be perceived unless it is carefully discussed in making out the scheme of river development. There can be no thoroughness of work where observation and explanation are slurred over or confused. After observation and description are well advanced, explanatory terms may be introduced ; it then being seen that such terms imply a pairing off of observed facts with the appropriate members of the deductive scheme. This mental process must become perfectly conscious ; its several steps must be recognized in their proper relations. No strong grasp of the subject can be gained until the student sees clearly where every part of the work stands in relation to the whole.

Topographical maps published by the U. S. governmental bureaus.— It is difficult to secure a full series of facts for laboratory study. My plan at present is to select maps from our own surveys and from the surveys of foreign countries, with little regard to locality, but with much regard to geographical features. The charts of our coast survey offer admirable illustrations of litoral forms. For example, the sand-bar cusps of Capes Hatteras, Fear, and Lookout, and their off-shore shoals, all formed between back-set eddy currents, rotating betwixt the Gulf stream and coast ; or the blunted Canaveral cusp on the Florida coast, and its southward migration from a former position ; or the fjords and islands of Maine ; the sounds of North Carolina ; the delta of the Mississippi, a geographical gem.[1] The maps of the Mississippi River Commission offer remarkable illustrations of the behavior of a large river on its alluvial plain. Its meanders, its cut-offs, and its ox-bow lakes are shown to perfection. The eight-sheet map of the alluvial basin of the Mississippi, prepared by this commission, can be had for a merely nominal charge ; it exhibits the lower part of the great river in an admirable manner. It tells the curious story of streams that descend from the eastern bluffs,

[1] It is not generally enough known that the illustrated catalogue of the Coast Survey Charts may be had free of charge on application by responsible persons to the Superintendent of the Survey in Washington.

but are unable to ascend across the flood plain to the Mississippi; they therefore unite and form the Yazoo river which runs southward along the eastern margin of the flood plain, near the foot of the bluffs. It would have to pursue an independent course all the way to the Gulf, were it not that the Mississippi comes swinging across the plain, and picks up the Yazoo at Vicksburg.

But it is the topographical sheets of the U. S. Geological Survey that afford the greatest variety of illustrative material for this country; and it is not too much to say that the facts they present create a revolution in the student's knowledge of his home geography. We may well wish that they were more accurate, but, with all their imperfections, they present a great body of new information. Under the family of plains there are examples of low litoral plains in New Jersey and Florida, the latter being so young that the constructional lakes are not yet drained. The moderate advance in denudation of an upland—itself an old lowland of denudation—is seen in the meandering gorge of the Osage in central Missouri; the relatively uncut plateaus of Arizona are seen alongside of the beginning of their denudation in the grand canyon of the Colorado. Maturely dissected plateaus are found in West Virginia and eastern Kentucky; in northern Alabama and northern Arkansas; but the first two are of minute topographic texture; the second two are of coarser forms. Outliers of past-mature plateaus are shown on several sheets in central Texas. All manner of other illustrations are found in the same series of maps. The thoroughly adjusted streams of the Pennsylvania Appalachians; the superimposed streams of northern New Jersey; the Illinois river, the type of a medium-sized river in the abandoned channel of a large river; this being the only well-mapped example of the kind in this country; the warped intermontane valleys of Montana; Crater Lake in northern California; glacial lakes in Massachusetts; flood plains slanting away from their river in Louisiana; fiords in Connecticut; moraines in Rhode Island; drumlins in Wisconsin; trap ridges in New Jersey; revived old mountains in North Carolina; half-buried mountains in Utah and Nevada. Every

new package of these maps brings some new illustration, which is put in use as soon as opportunity allows. One of the latest is a peculiar case in Southern California : a number of small rivers are here seen running down from the Coast range to the shore of the Pacific ; but their mouths are all shut up by sand-bars in the most summary manner ! A curious trick for a Pacific ocean to play on some trifling little streams that one would think were beneath its notice.

These maps are simply indispensable. They call forth much interest from the class. At first hardly translatable into words, their meaning grows plainer and plainer, until at the close of the course they are as suggestive as they were uncommunicative at the beginning.

Foreign topographical maps.—Not less valuable and far more accurate than our own topographical sheets are those of various foreign topographical surveys. Unfortunately the relief in most of these is expressed by hachures ; altitudes being given only for occasional points, or by widely separated contour lines ; but the general expression of the surface is certainly admirably rendered in many of the surveys. The older maps are generally too heavily burdened with hachures ; but the more modern surveys are very artistically executed. It has been my practice for several years past to select certain groups of sheets from the sets of foreign topographical maps in our college library, and order extra copies of these groups, mount them on cloth and rollers, and thus prepare them for the most convenient use in the laboratory. Both the library and laboratory collections of this kind are increasing year by year, and I shall soon prepare a special account of the grouped sheets, in the hope that others may perceive their great value and introduce them as teaching materials as far as possible. Without specifying all that have been thus far secured, I may briefly mention some of the more interesting examples.

From the Army Staff map of France (1 : 80,000) there is a group of sheets showing the level plain of the Landes, with its exceptionally straight shore line and its wide belt of litoral sand

dunes; the beautiful group of radial rivers, flowing down the slopes of a great alluvial fan that has been formed where several large rivers emerge from the Pyrenees, this being one of the best examples of a simple consequent river-grouping that I have found; the plateau of the lower Seine, an old upland of denudation, with an excellent meandering river gorge of moderate depth cut through it, together with certain interesting features of young branching river valleys, and of rivers that have been shortened by the encroachments of the sea in cutting away the land. To these I intend shortly to add groups of sheets showing the dissected escarpment west of Rheims and Chalons, with its beautifully adjusted rivers, the delta of the Rhone, and the fiorded coast of Brittany.

From the Ordnance Survey of Great Britain (1 : 63,360) one set of sheets includes the central Highlands of Scotland, with the Great Glen and Glen Roy; two other sets include the fiords and islands of the southwestern and the northwestern coasts. These three sets agree in showing an old peneplain of denudation, then elevated and maturely dissected, and now somewhat depressed, with cliffs nipped on its land heads and deltas laid in its bay heads. Their formula, according to the plan already suggested, would be 75, + 25, − 2. A glacial accident of late date is recorded by the upland tarns and the valley lakes. A group of sheets for southwestern Ireland exhibits bold mountain ranges running directly into the sea, forming a strongly serrated coast. The English sheets are of older date and are not of particularly good expression, and for this reason I have not yet ordered any of them; although the ragged escarpment of the chalk and of the oölite trending northeast on either side of Oxford should be represented; and the Weald offers excellent illustration of well adjusted consequent and subsequent rivers on an unroofed dome of Cretaceous strata.

The map of the German Empire (1 : 100,000) supplies many examples of striking features. The plateau of the Middle Rhine has already been mentioned as a subject for lantern slides; it is represented in two map-groups, one of which shows the tranverse

gorge of the Rhine; the other includes the meandering gorge of the Moselle, with a perfect showing of its abandoned cut-offs among the hills. The flood plain of the Rhine about Mannheim exhibits the former meanders and the present controlled course of the river, foreshadowing the future control of the Mississippi; the morainic country of Prussia is a medley of hills and hollows; the Vistula turns sharply at its Bromberg elbow from the valley that it once followed, but which it now abandons to the little Netze; long curving sand bars form the two enclosed bays of eastern Prussia (the Frische and Kurische Haffe). From Norway (1 : 100,000), the district of the Christiania fiord is already received in ten sheets of most delicate execution; the greater fiords of the western coast will be ordered as soon as fully published. From Russia (1 : 400,000), the lakes of Finland, and of the lower Danube. From Austria, a portion of the flood plain of the Danube, and a strip of the fiorded coast of the northern Adriatic. This is only a beginning of what I hope the collection may be in a few years.

I cannot speak too highly of the educative quality of these grouped sheets. It is, in the first place, a good thing for students to inspect, as closely as they may in laboratory work of this kind, the very best products of geographical art. Their ideals are thus raised above the commonplace level. Whatever they afterwards see will be compared with a high standard. A feeling of dissatisfaction will arise regarding the very inferior maps of their home states, to which they have been inured, and from this a demand will grow for the continuation and improvement of the mapping of our country that is now going on. In the second place, the facts of the subject are placed before the student so closely that he cannot fail to be impressed at once with their real features; and these he will find so numerous and so varied that he will perceive the need of serious study for their apprehension. No verbal descriptions from the teacher suffice to replace the portrayal of geographical relief on good maps.

Classification of constructional forms.—It is only after the deductive scheme is well advanced, and after many examples of

facts have been correlated with it, that I introduce a classification of constructional forms. Some such classification is essential, but it is difficult to establish satisfactorily, because of the endless variety of structures found in nature. At present in the elementary course I recognize only plains and plateaus of horizontal strata; mountains of disordered strata, with many minor subdivisions; and in a subordinate way, volcanic cones and flows, and glacial hills and moraines. Like the more difficult orders of plants in an elementary course on Botany, mountains must be treated briefly in an elementary course on Physical Geography, and their fuller treatment left for more advanced study. After the various kinds of constructional forms are treated, it is advisable to review the features of rivers, with their divides, lakes, waterfalls, flood plains, and deltas; and in this connection a week or two may be given to the forms assumed by the waste of the land on the way to the sea. The distribution of different kinds of forms should be briefly given with their classification.

When thus developed, Physical Geography may worthily claim the dignity of a University study. Its subject matter is of importance in itself, as well as in its relations to geology, zoölogy and botany, or to history and economics. Its methods are of value in training various mental faculties: observation, description, generalization; imagination, comparison, discrimination; these are all cultivated to a high degree in the student who successfully utilizes the opportunities of the course.

Two other aspects of the subject may be briefly considered.

Areal geography.—The study of the fauna and flora of a region or of a continent requires the examination of all of its animals and plants according to some acceptable scheme of classification. The study of the areal geology of a region involves the examination of its formations in their order of local occurrence, but also with regard to the general, world-wide scheme of geological classification. In the same way, the study of the areal geography of a country or of the world calls for the recognition of the parts that compose the whole, of their location and area, and of

their classification according to some rational and comprehensive scheme. Geographical descriptions now current are very defective in the latter respect. They are for the most part empirical; and like empirical descriptions generally, they are short-sighted or blind. One of the difficulties in the way of improvement lies in the need of geological data; for without sufficient information as to geological structure and history, no satisfactory geographical description can be written. It might from this be inferred that, where the geology of a region had been deciphered, the geologist could give an account of its geography as well; but judging by the existing condition of these two branches of earth-science, such is not the case. A great part of the facts that are essential to the geologist are not needed by the geographer. Many considerations that are important to the geographer receive little attention from the geologist. Each is fully occupied in his own special field. Advance in the study of areal geography, therefore, calls first for proficiency in systematic geography, next for a knowledge of general geology and of the local geology of the region to be studied, and finally a special geographical examination of the region. With such a preparation, a course might be planned on the physical geography of Europe, or of the United States; and either course might occupy half a year or a year very profitably. Most of the examples already introduced in the elementary systematic course would here be found again, and many others with them, until the whole area of the country was covered.

Geographical investigation by the state surveys.—The chief difficulty in planning such a course is the scarcity of good geographical material; but, on the other hand, one of the chief interests in geography comes from the opportunities that it offers for new investigations. When we inquire into the generally impoverished condition of geographical teaching in our schools, the main difficulty is undoubtedly to be found in the deficiency of good geographical literature, both in text books and in collateral reading, ready for teachers' use. Consider the case of Ohio, for example. Where shall the inquiring teacher in that state turn

for a rational account of its physical features, presented in the light of modern research? No such account exists. The Empire state is no better off; perhaps not so well. In both these states, as in all others, local physical geography is a most attractive field. It is through this field that the scholars should be led out to see the rest of the world; yet the teachers have not sufficient means of presenting the facts of the subject to their classes. To most persons the facts of our home geography are really unknown. A few investigators, mostly members of geological surveys, possess a more or less intimate personal knowledge of their states; but it is too often stored only in their minds, and there remains inaccessible to others, unless by personal interview. It is indeed rather curious that the state geological surveys have not before now undertaken systematic geographical descriptions of their areas; much more extended than the too brief chapters with which the serious geological descriptions are often prefaced. The geographical descriptions will never be well done until they are made the work of well trained specialists, whose first attention is directed to this subject. The stratigrapher, the petrographer, and the paleontologist are too fully occupied with their own studies to undertake geographical studies at the same time, even if they had the proper preparation for doing so. The effort at double investigation is seldom successful. In the present stage of study it is more economical to give each investigator a single problem over a whole state, than to assign to one person all the problems of a limited district.

It does not seem improbable that in the near future a number of our state surveys may undertake studies in this neglected field, and thus furnish to a new class of readers a fund of material for which they have long been waiting. The teachers of a state will welcome geographical chapters in the annual reports of their survey on the physical features of their home district. The surveys will certainly welcome the new support and interest that will thus be awakened in their work. The geographical chapters may for a time have to be prefaced with introductions, after the

style of those geological synopses by which many of our state reports are opened. The accounts of a certain group of geographical features should always involve the comparison of local examples with those from other regions, much as the paleontologist or the petrographer makes his comparisons of home and foreign examples of fossils or rocks. The chapters must be written in simple style, for many teachers must use them as reference books. They must be well illustrated, for most teachers will have no other pictures of their home district, however well they may be supplied with views of foreign countries. They must, above all, be prepared in accordance with a well considered geographical system. The chapters should not be so long as to fatigue or repel, but rather so short as to awaken an appetite for more reading of the same kind. They should be published not only in the usual annual reports, but also as separate pamphlets for distribution to all schools through the state superintendent of public instruction. Studies of this kind promise to offer most attractive subjects for geographical investigation for many years to come.

There is another and quite different direction in which good work should be done by the trained geographer. That is in the preparation of maps and illustrations for school books. It is manifest enough in examining the maps now in use that they have been drawn by draftsmen, not by geographers. Their lines show no sufficient knowledge of the facts that should be represented. They are simply copies of other maps, with no sufficient expression of meaning. The relief of the land is generally so poorly represented on school maps that no criticism of its execution will make it right; it must be done over again. The outlines of coasts and the courses of rivers are often merely caricatures of the facts. The meaningless irregular curves of Cape Cod and of the Carolina coast offer amusing illustrations of this in many a school geography. The student of geography, who prepares for his work by a good foundation in geology, who carries his geographical studies to the point of original investigation in different parts of the country, and who has a happy

facility in drawing and, if possible in modeling also, may rest assured of a busy future after his apprenticeship. His services will be in demand by more than one publisher as soon as his work is known.

W. M. DAVIS.

HARVARD UNIVERSITY, December, 1893.

EDITORIALS.

IT has been announced that the Board of Directors of the Geological Survey of Missouri have decided to publish only three more reports, viz.: those on paleontology, on clays, and on lead and zinc; and "to abandon other work on reports on hand, whether nearly completed or not," as well as to discontinue the survey after June 1, 1894.

We hope that this report is entirely erroneous. If it is true, however, those who have followed the history of the Geological Survey of Missouri will hear the news with deep regret. The first appropriation for the present survey was made by the legislature in 1889, and in the fall of that year Mr. Arthur Winslow was appointed State Geologist. Since that time the work of the survey has been rapidly and intelligently developed, and a number of valuable reports have been issued. Though these reports contain a great amount of information, there is vastly more yet which should, and would, if unhindered, appear in later volumes. In the work of a state geological survey the different subjects discussed are not worked up entirely independently of each other, but in the collection of data in the field on one subject, the geologist collects incidentally many facts relating to other subjects which he expects to treat of at a subsequent time. As a result of this, the amount of information on all points of scientific or economic importance is steadily increasing in the office of the state geological survey; and every report that is published means not only that the subject to which it relates has been thoroughly investigated, but also that many facts relating to other matters of general interest have been collected, and will, at some future time, be supplemented by additional facts and form the basis of other reports.

When a survey has completed its work on most subjects and has but little left to publish, its discontinuance, though it may be

premature, is not so injurious as when a survey like that of Missouri, which has just reached maturity, and is in its most active and useful stage, is suddenly discontinued. Great quantities of unpublished information relating to many different subjects and in various degrees of preparation are absolutely lost to the state, for much of such information is necessarily too incomplete to be published without further field work. It has been collected, however, at very considerable expense, and much of it, with a little more time, would be ready to be published and would become of lasting benefit to the state.

By the premature abolishment of a survey, therefore, the state loses not only the money actually invested in these unfinished reports, but it loses the reports themselves, which are on subjects in which almost every citizen in the state is either directly or indirectly interested. More than this, in dispensing with a state geologist and his staff, who for years have been actively and intelligently fulfilling the functions of their offices, the state also loses the benefit of the vast amount of general experience in the region that they have acquired during their investigations. If the survey is ever reorganized, the new officials must not only acquire the same experience over again, at the expense of the state, but they must also collect again the facts lost on the discontinuance of the preceding survey.

The history of many states shows that several times they have organized surveys and then abolished them before the work was completed, or even fairly started; and that perhaps years later they have organized new surveys. In some cases this procedure has been repeated so many times that the advantages gained have cost the state immensely more than they would have done if the first survey had been continued to completion. Missouri itself has had several such experiences, and the friends of the state had hoped, when the present survey was inaugurated, that it would be continued until all its great geological and mining resources had been fully investigated.

In a number of cases, in times of financial depression, state legislatures have been obliged to curtail their expenditures; and

though, as has been shown, it is very unwise to decrease the requisite appropriation for a geological survey, yet if, under such circumstances, it is necessary to do so, the office of state geologist and its incumbent, if he is efficient, should nevertheless be retained, for he possesses facts on unfinished work and a general experience of the region which will mean many thousands of dollars to the state when the survey is reorganized.

It is to be sincerely hoped that the Board of Directors of the Missouri Survey will follow the wisest course. If the finances of the state require the reduction that has been made in the appropriation for the geological survey, let this be only temporary, and let the office of state geologist and its present representative be retained. Mr. Winslow has held this position since the present survey was inaugurated; he has managed the affairs of the survey in a most energetic and capable manner, and the volumes on coal, iron, mineral waters, and other subjects attest to the activity of himself and his staff. Much of this work he has accomplished in the face of the many difficulties that no one but those who have had personal connections with state geological surveys can appreciate; and yet his publications speak for themselves in their completeness and the thoroughly scientific methods with which he has treated the problems before him. He has already performed a great service to the people of Missouri and the public in general, and it is to be hoped that the Board of Directors will not permit the state to lose the man who is more necessary than any other to the successful completion of the geological survey. We recur to the hope expressed at the outset that the report of discontinuance is erroneous.

R. A. F. P., Jr.

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The Boston meeting of the Geological Society of America was remarkable for the large number of papers submitted, fifty-nine, and for the unusual geological activity which these indicated. In an uncommon degree the papers represented recent active investigations. To only a slight extent were they rehearsals of

old studies. Of the fifty-nine papers presented, eleven may be classified as petrological, twenty-two as structural and stratigraphical, four as physiographic, three as paleontological, eight as glacial, four as taxonomic, and the remainder as miscellaneous. On the whole, the papers showed wide diversity of interest and an admirable distribution of investigation. Notable interest was manifested in the petrological papers, particularly those relative to volcanic phenomena, and in the papers bearing on structural dynamics. The titles were as follows:

Some Recent Discussions in Geology. (Presidential address). Sir J. William Dawson.

Geological Notes on some of the Coasts and Islands of Behring Sea and its Vicinity. George M. Dawson.

Fossil Flora of Alaska. Frank H. Knowlton.

New Discoveries of Carboniferous Batrachians. Sir J. William Dawson.

Cenozoic Geology along the Apalachicola River. William H. Dall and Joseph Stanley-Brown.

Geological Activity of the Earth's Originally Absorbed Gases. Alfred C. Lane.

Certain Climatic Features of Maryland. William B. Clark.

Dual Nomenclature in Geologic Classification. H. S. Williams.

Johann David Schoepff, and his Contributions to North American Geology George Huntington Williams.

Relations of Synclines of Deposition to Ancient Shorelines. Bailey Willis.

An Account of An Expedition to the Bahamas. Alexander Agassiz.

Lacustrine Tertiary Formations of the West. William B. Scott.

Geology of the Coosa Valley in Georgia and Alabama. C. Willard Hayes.

Geological Structure of the Housatonic Valley lying east of Mt. Washington. William H. Hobbs.

The Hibernia Fold, New Jersey. J. E. Wolff.

Tertiary Dislocations of the Atlantic Coast of the United States. N. S. Shaler.

Relations of Mountains to Continents. N. S. Shaler.

Phenomena of Beach and Dune Sands. N. S. Shaler.

Eastern boundary of the Connecticut Triassic. W. M. Davis and L. S. Griswold.

Geographical Work for State Geological Surveys. W. M. Davis.

Facetted Pebbles on Cape Cod. W. M. Davis.

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Crustal Adjustment in the Upper Mississippi Basin. Charles R. Keyes.

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A Prismatic Stadia Telescope. Robert H. Richards.

Ancient Volcanic Rocks along the Eastern Border of North America. George Huntington Williams.

Ancient Eruptive Rocks in the White Mountains. C. H. Hitchcock.

The Chemical Equivalence of Crystalline and Sedimentary Rocks. G. K. Gilbert.

Volcanite, an Anorthoclase Augite Rock chemically like the Dacites. William H. Hobbs.

Further Notes on the Occurrence of Albertite in New Brunswick, Canada. H. P. H. Brumell.

Alterations of Silicates in Gneiss at Worcester, Mass. Homer T. Fuller.

Pre-paleozoic Decay of Crystalline Rocks North of Lake Huron. Robert Bell.

Gabbros on the Western Shore of Lake Champlain. James F. Kemp.

Notes on the Occurrence of Mica in the Laurentian of the Ottawa District. Robert W. Ells.

Intrusive Sandstone Dikes in Granite. Whitman Cross.

Age of the Auriferous Slates of the Sierra Nevada. James P. Smith.

Origin of the Coarsely Crystalline Vein Granites, or Pegmatites. William O. Crosby.

A Classification of Economic Geological Deposits, based upon Origin and Original Structure. William O. Crosby.

Lake Cayuga a Rock Basin. R. S. Tarr.

Pleistocene Problems in Missouri. James E. Todd.

Remarks upon a supposed Glaciated Stone Axe from Indiana. G. Frederick Wright.

Pseudo-Cols. T. C. Chamberlin.

Certain Features of the Past Drainage Systems of the Upper Ohio Basin. T. C. Chamberlin and Frank Leverett.

Glacial History of Western Pennsylvania. G. Frederick Wright.

The Ancient Strait at Nipissing. F. B. Taylor.

Extramoraine Drift between the Delaware and the Schuylkill. Edward H. Williams.

Interglacial Series of Germany. Professor Dr. Alfred Teutzsch, Königsberg, Prussia.

The Madison Type of Drumlins. Warren Upham.

Diversity of the Glacial Drift along its Boundary. Warren Upham.

Notes on the Microscopic Structure of Siliceous Oölite. E. O. Hovey.

T. C. C.

Reviews.

Rügen. Eine Inselstudie. By Dr. Rudolf Credner, Professor in the University of Greifswald. Forschungen zur deutschen Landes- und Volkskunde, No. 5, Vol. 7. Stuttgart, Engelhorn, 1893.

Through the special mention of this interesting monograph, I wish to call the attention of studious American readers to the valuable series of essays, edited by Professor Kirchhoff of Halle, and published under the above title. The earlier numbers contain such papers as *Die oberrheinische Tiefebene und ihre Randgebirge*, by Lepsius; *Der Einfluss der Gebirge auf das Klima von Mitteldeutschland*, by Assmann; *Gebirgsbau und Oberflächengestaltung der Sächsischen Schweiz*, by Hettner; *Die Kurische Nehrung und ihre Bewohner*, by Bezzenberger; *Der Rhein in der Niederlanden*, by Blink; *Die Ursachen der Oberflächengestaltung des norddeutschen Flachlandes*, by Wahnschaffe. The numbers announced to appear shortly are no less attractive: *Die Norddeutschen Urstromsysteme*, by Berendt; *Die Eifel*, by Follmann; *Der Boden von Schleswig-Holstein*, by Haas; *Bau und Entstehung des Harzgebirges*, by Klockmann; *Bau und Entstehung des Erzgebirges*, by Sauer. There are many others of biological or ethnological interest, about forty studies having now been published. The price of the separate numbers varies from one to eight marks. Subscribers who now purchase the whole series may have the first five volumes for half price.

These studies were begun in 1882, in consequence of an appeal to German geographers and geologists issued by Professor Richard Lehmann. A central commission was formed, under which various lines of work were prosecuted. The most important of these are: the *Forschungen*, here referred to; various bibliographic lists, published by local scientific societies, in which everything bearing on home geography is carefully enumerated; and an *Anleitungen zur Deutschen Landes- und Volksforschung*, prepared by various experts. An impulse towards the scientific study of the Fatherland has thus been given, which is bearing rich fruit. The next century ought to see something of the kind in this country; for there is a phase of geologico-geographical literature that is more appropriately associated with unofficial publica-

tion than with reports of state or national surveys. At present, however, the more active state surveys offer the best approach to work of this class, and with the recently increasing interest in physiographical investigation, I hope to see chapters of their annual reports devoted to well illustrated essays of this character.[1]

Rügen, a composite island on the Baltic coast of Prussia, has long attracted attention of geologists from the peculiar dislocations of its Cretaceous strata, in which glacial till was peculiarly involved; so that some observers concluded the dislocations were the product of pressure from the advancing ice sheet. Credner now concludes in effect as follows: The Cretaceous strata, while still horizontal, were overspread by a sheet of till. The compound mass was then, after the disappearance of the ice sheet, fractured and dislocated in a rather irregular manner, although the lines of movement in a measure follow systematic courses. A new constructional topography was thus produced; and a significant advance was made in its subaërial denudation. Then a second ice sheet crossed the Baltic, rubbed over the uneven surface of Rügen, softened its surface expression, and distributed an irregular deposit of drift over the Cretaceous beds and the older drift. Since then, a moderate depression has submerged part of the region, converting Rügen into a group of islands; and these have been in still later times soldered together by sand bars.

Concerning the evidence thus gained of a complex glacial period, Credner remarks: A convincing proof of the long interval between the two glaciations is found both in the heavy fracturing and faulting that took place between the deposition of the two northern drift formations; and in the distinct denudation that was suffered by the constructional forms produced by the dislocations, before the deposition of the second drift (p. 416, 417).

W. M. DAVIS.

[1] See The Improvement of Geographical Teaching, Nat. Geogr. Magazine, IV., 1893, 74.

Analytical Abstracts of Current Literature.

SUMMARY OF CURRENT PRE-CAMBRIAN NORTH AMERICAN LITERATURE.[1]

Ells[2] gives a description of the Laurentian of the Ottawa district. A reëxamination of the Trembling Mountain section shows that, instead of its being a continuous ascending series, there are no less than three anticlines and their corresponding synclines, and the section is still further complicated by faults of every considerable extent. But one limestone was found, that of Trembling Lake, and this instead of being interstratified with the orthoclase gneiss is in the form of a synclinal overlying this gneiss. This limestone at no point was observed to be more than 50 feet in vertical thickness.

In the region between the anorthosite area and the Gatineau river the limestone in nearly every case occupies well defined synclinals separated by anticlinals of the underlying gneiss. In this area it has been found impossible to trace any bands of limestone to any considerable distance continuously, the limestones being often local in their development, and lenticular in form.

In the limestone in certain places are masses of quartzose rock and crushed gneiss, presenting the aspect of a true conglomerate. As to the thickness of the gneiss, on the Rouge river, the most favorable place found for measurement, the section gave a thickness of 10,000 feet beneath the limestone, if there is no break, but this figure may not be accurate, as faults and repetitions of strata may occur at several places.

Intrusive within the gneiss and limestone are the anorthosite and syenite masses of Grenville and Chatham, and other less conspicuous masses. No less than six or seven clearly distinguished periods of intrusion can be recognized. The augen gneiss of the Rouge river is probably also an intrusive.

[1] Continued from Vol. I., p. 541.

[2] The Laurentian of the Ottawa District, by R. W. Ells. Bull. Geol. Soc. of Am., Vol. IV., pp. 349–360.

The succession in the district, as determined in ascending order, is (1) reddish grey gneiss without distinct signs of bedding or stratification, but with a foliated structure; (2) reddish orthoclase-gneiss interstratified with hornblendic, quartzose, and garnetiferous gneiss and beds of quartzite, the whole showing a well stratified arrangement of beds; (3) grayish and rusty gneiss passing gradually upward into the calcareous portion of the system, between the gneiss and the limestone there being interstratifications of the two; and (4) schistose, sericitic, chloritic, and micaceous schists of the Hastings series. This division overlies the crystalline limestone, and is believed to represent the lower member of the Huronian system. This arrangement of the Laurentian accords very closely with that in New Brunswick, as given by Bayley and Mathew. Unconformable upon the Laurentian of Ontario is the Paleozoic.

Adams[1] describes the anorthosite of Canada, and gives its relations to the surrounding rocks. The great mass of the Archean of Canada is composed of an orthoclase-gneiss, which is in many places laminated, but is in large part little laminated, and probably of eruptive origin. Much of the laminated gneiss is probably sedimentary. In certain regions the laminated gneiss is interlaminated with crystalline limestones, quartzite, amphibolite, etc. This series is a higher part of the Laurentian, and was called by Logan the Grenville series; while the lower gneiss, which does not bear any of this rock, was called the Ottawa gneiss. The limestone, graphite, etc., are evidences of the existence of life during the deposition of the Grenville series, and this was the earliest life of the planet.

All of the minerals of economic importance occur in the Grenville series. The relations of the Grenville series to the Ottawa series have not been certainly determined, but it is probable that the Grenville series lies discordantly upon the old gneiss, the upper series being sediments originally like those that are deposited to-day.

The anorthosite group, or Upper Laurentian of Logan, is an eruptive rock belonging to the gabbros. It is characterized by a predominance of plagioclase, which frequently is the only mineral of the rock. The rock is hard and originally was completely massive. This original structure has been modified so as to take on an extraordinary cataclastic structure, which has also given the rock a schistose character. This is not ordinary dynamic metamorphism, but is caused by a movement of the rock mass while it was deeply buried and near its melting point.

The anorthosite, although so regarded by Logan, is not a distinct sedi-

[1] Norian oder Ober-Laurentian von Canada, ADAMS, F. D. Inaugural-Dissertation zur Erlangung der Doctorwurde der Universität zu Heidelburg. 1893.

mentary geological formation, but it is discordantly upon the gneiss of the Laurentian by intrusion. Its intrusive character is shown by the following facts: it is a plagioclase gabbro; it cuts across the Laurentian schists; it holds as inclusions blocks of gneiss; about its masses forming girdles are many characteristic contact belts. The areas of anorthosite are isolated, and lie along the border of the Archean continent of that time exactly as the volcanoes of to-day are along the continental borders. In the great interior area of Laurentian no anorthosite has been found. The formation is all pre-Cambrian, as shown by the fact that it lies unconformably below the Cambrian. Also before the Cambrian was deposited it received its metamorphism, and was deeply eroded. Its relations to the Huronian have not been determined, but it probably does not belong to the Huronian period, but rather to the closing part of the Laurentian.

The several regions of anorthosite are described separately, that of Morin and Saguenay being most fully considered. The Morin area is surrounded by the Grenville series. In the Grenville series are interlaminated limestones, bands of which can be traced many miles. Within the limestone are frequently thin layers of the gneiss. The limestone is less resistant and more plastic than the gneiss. As a result of folding, the bands of gneiss have been broken up, producing irregular banded blocks, which are isolated in the limestone in such a manner as to give rise to extraordinary pseudo-conglomerates.

The Saguenay region is of great size, 5,800 square miles. It is surrounded on all sides by the orthoclase-gneiss, or Ottawa gneiss. The anorthosite of this district is more basic than that of the Morin district, the plagioclase frequently being labradorite or bytownite. That it is an intrusive is shown by the same facts as in the Morin area.

Comments.—The time of pre-Cambrian life must have been so vast that it is not safe to assume that the rocks of the original Laurentian bear the remains of the first life of the planet. Indeed, it seems probable that the earliest life left in the rocks no permanent evidence of existence. Further, before it can be assumed that the Ottawa Laurentian bears the oldest remains of life, it must be shown that these rocks are older than any other series bearing life remains.

Adams describes the typical Laurentian areas of Canada.[1] The basement rock here found is the Fundamental Gneiss. It is uniformly reddish or grayish orthoclase-bearing gneissoid granite, poor in mica, and bisilicates. The foliation is often due to movement in a plastic condition. Dark bands of amphibolite

[1] On the Typical Laurentian Areas of Canada, by FRANK D. ADAMS. Journal of Geol., Vol. I., No. 4, pp. 325–340.

are not uncommon, and hornblendic and pyroxenic gneiss appears in some places. The Fundamental Gneiss, so far as at present known, is a complicated series of rocks, for the most part of unknown origin, but comprising a considerable amount of intrusive material.

In certain parts of the Laurentian area, and notably in the Grenville district, the Laurentian has a different character. In the Grenville series the orthoclase-gneiss is still the predominating rock, although it here has a greater variety of mineralogical condition, and is frequently well foliated. Amphibolites, hornblende-schists, heavy beds of quartzite, and numerous thick bands of crystalline limestones, are all abundant and interstratified with one another. In the series are ores, and a wide variety of minerals. In the limestone and associated rocks graphite is often widely disseminated. This does not occur in the Fundamental Gneiss. The areas occupied by the Grenville series while together aggregating many thousands of square miles, are probably small as compared with those of the Fundamental Gneiss. The Grenville rocks, while generally highly inclined, over some large area are nearly horizontal, but even in these cases they have been subjected to great pressure.

As to the origin and relations of the Fundamental Gneiss and the Grenville series, three views may be taken :

1. The Fundamental Gneiss may be the remains of a primitive crust penetrated by great masses of igneous rocks and having been subjected to repeated dynamic movements. The Grenville series may be an upward continuation of the Fundamental Gneiss under altered conditions, marking a transition from a primitive crust to normal sediments. Thus the two would form one practically continuous series. The general petrographical similarity of the two series, taken in connection with the more varied nature of the Grenville series, its frequent stratified character, and the presence in it of limestones and graphite indicating an approach to modern conditions and the advent of life, together with the difficulty of clearly separating the two series from each other and defining their respective limits, lend support to this view.

2. The Grenville series may be considered as distinct from the Fundamental Gneiss, and reposing on it uncomformably, being a highly altered series of clastic origin, the Fundamental Gneiss having some such origin as suggested above or being an older series of still more highly altered sediments. As it is now thoroughly crystalline, there is, however, no absolutely conclusive proof that even the Grenville series is of sedimentary origin. However, the series is in all probability made up, in part at least, and perhaps wholly, of sedimentary material, but as this is not absolutely shown, the proposal to separate it from the rest of the Laurentian and class it as Algonkian or Huronian seems premature.

3. The Fundamental Gneiss may be considered as a great mass of eruptive rock, which has eaten upward and penetrated the Grenville series, while the Grenville series itself represents a series of altered sediments of Laurentian, Huronian, or subsequent age. The world wide distribution of the Fundamental Gneiss (forming as it does, wherever the base of the geological column is exposed to view, the foundation upon which all subsequent rocks are seen to rest) is opposed to this view, as is also its persistent gneissic or banded character.

The anorthosite series is a gabbro, often regularly laminated and much altered, which is intrusive within the Fundamental Gneiss and the Grenville series.

The Hastings series has a very local development. It consists largely of calc-schists, mica-schists, dolomites, slates, and conglomerates, thus containing much material of undoubtedly clastic origin. The whole district has been subjected to great dynamic action, some of the pebbles of the conglomerates being distorted in the most remarkable manner. This series may be equivalent to a part of the original Laurentian, may follow above the Grenville series, or may prove to be an outlying area of Huronian rocks folded in with the Laurentian.

The whole of the above series was cut by various acid and basic rocks, metamorphosed and folded before upper Cambrian time, since the Cambrian sediments rest upon them unconformably, and contain fragments of the lower series which show that when deposited they were in their present condition.

The roche moutonnée surface possessed by the eroded Laurentian rocks was impressed upon them in the first instance in pre-Cambrian times, for along the edge of the nucleus from Lake Superior to the Saguenay, the Paleozoic strata may be seen to overlie such surfaces showing no traces of decay, and similar to that exposed over the uncovered part of the area. To what extent the Cambrian, Devonian, and Silurian seas passed over the Laurentian cannot be determined, but it seems probable that in Cambrian times, a not inconsiderable part of the Archean Nucleus was under water, as shown by various outliers of these rocks. What evidence there is indicates that the area in later Paleozoic, Mesozoic, and earlier Tertiary times, was out of water, being subjected to deep-seated decay and denudation, culminating in the glaciation of Pleistocene times. These processes removed all but remnants of the Paleozoic strata.

Comments.—The question may perhaps be asked whether the visible contacts of the pre-Cambrian and Cambrian are sufficiently extensive to warrant the statement that the pre-Cambrian topography was similar to the present topography. May not the tendency to carry in imagination the present forms under the Cambrian have been given undue weight?

Lawson,[1] in 1893, on lithological grounds suggests the following hypothetical correlation of certain rocks of Western Ontario and Minnesota, Eastern Ontario and Quebec:

	WESTERN ONTARIO AND MINNESOTA.	EASTERN ONTARIO.	QUEBEC.
In order of superposition.	Ontarian system.	Hastings series.	Grenville series.
	Laurentian system.	Ottawa gneiss.	Ottawa gneiss.
	Carltonian-Anorthosites of Minnesota.		Norian.
In order of chronological sequence; an irruptive rock being of later age than the formations which it invades.	Carltonian-Anorthosites of Minnesota.		Norian.
	Laurentian system. — Batholitic granites and gneisses.	Ottawa gneiss.	Ottawa gneiss.
	Ontarian system.	Hastings series.	Grenville series.

Comments.—It seems to the reviewer that such lithological correlations between rocks in different and widely separated geological provinces have no value. The reasons for this belief cannot be here stated, but they have been published in Bull. No. 86, U. S. Geol. Survey.

Barlow[2] describes the Laurentian granites and gneisses as intrusive in the Huronian rocks north of Lake Huron. The localities described are Killarney Village; Beaver, Fox, Balsam, Three Mile, Brush, Camp, Crooked, Johnny, Panache, Wavy, Chief's, Daisy, Baby and Alice lakes; Goshen, Broder and Dell townships; Wahnapital river; Cartier and Straight Lake Stations; and two islands near Thessalon. As evidence of the eruptive nature of the Laurentian gneiss in the Huronian sediments are cited the diverse stratigraphic relations of the rocks along their line of junction; the invariable alteration of the sedimentary rocks along the contact line; the inclusion of angular fragments, clearly referable to the adjacent sedimentary strata in the gneiss; the occurrence of gneissic intrusions and apophyses of pegmatite, occurring in or lam-

[1] The Norian Rocks of Canada, by A. C. LAWSON. Science, Vol. XXI., No. 538, pp. 281–282.

[2] Relations of the Laurentian and Huronian Rocks North of Lake Huron. By A. E. BARLOW. Bull. Geol. Soc. of Am., Vol. IV., pp. 313–332.

inated with, and cutting across the bedding of the Huronian rocks; the absence of sedimentary rocks within the gneiss, and the general character of the gneiss, which in appearance and behavior more nearly resembles an eruptive granite than an altered sedimentary rock. It is therefore concluded that the Huronian is the oldest series of sedimentary strata in this region, and that the floor upon which these were lain down must have been subsequently fused and recrystallized.

Comments.—That in many localities there are granites and gneissoid granites intrusive in the Huronian of Lake Huron has been well known since the days of Logan. However, because a part of the granites are intrusives later than the Huronian, this does not show that the basement upon which the Huronian was laid down does not still exist, in part at least, as held by Logan, Irving, Pumpelly, and others. The account of the facts and their interpretation at the contacts near Thessalon by Barlow are so irreconcilable with those given by Pumpelly, Irving, and myself, that the former or the three latter must have wholly failed to grasp the truth. These latter hold that there is here the most manifest evidence of profound unconformity between the Basement Complex and the Huronian. Should this position prove correct, the question would naturally arise as to what extent the accounts of the remaining localities described by Barlow need revision.

Smith,[1] in 1893, gives a general description of the Archean rocks in the southern half of the Rainy Lake district in the Province of Ontario, between the Thunder Bay district and the Lake of the Woods. The rocks here found are divided into the Lower Archean and Upper Archean, the term Archean being defined to include all pre-Cambrian rocks. The Lower Archean series, or Laurentian, comprises a lower granitic and syenitic division, and an upper micaceous, hornblendic and trappean division, for the most part schistose. The first usually occurs in rounded or ovoid areas, between which are the rocks of the Upper Archean or Ontarian.

The Ontarian system includes the Contchiching and Keewatin series. The Contchiching rocks are mainly mica-schists, and have an estimated thickness of 9,000 feet, the apparent thickness of 24,000 to 29,000 feet, given by Dr. Lawson, being believed to be due to multiple folds. These mica-schists are regarded as clastic in origin, because of their fine and even lamination. The Keewatin consists for the most part of plutonic, volcanic, and pyroclastic rocks, although in some of the upper members there are more or less aqueous sediments. The Contchiching and Keewatin are everywhere in strict conformity, although at the base of the Keewatin in certain localities there are conglomerates regarded as local and volcanic.

[1] The Archean Rocks West of Lake Superior. By W. H. C. SMITH. Bull. Geol. Soc. Am., Vol. IV., pp. 333–348.

The Laurentian granites and gneisses are intrusive in the Ontarian, and are therefore younger, the relations between the two being the same as described by Lawson in the Rainy Lake district.

Resting discordantly upon the Laurentian and Ontarian rocks, is the Steep Rock series, presumably of Archean age. This series is believed to be a folded syncline, rather than a monocline, as described by Smyth. As the Animikie series exhibits no such folding, the inference is strong that the Steep Rock series is older than the Animikie. While the unconformity between the Steep Rock series and Laurentian is undoubted, the unconformity between the Keewatin of the Seine river and the Steep Rock Lake series is not at all obvious. Lithologically the two series are strikingly similar, and could not be separated by the most careful study. It would seem that to the west of Steep Rock Lake this series has been faulted up and swept away, so that it is really unconformably above the Keewatin. The Atic Oban series is an eruptive one probably belonging to the Keewatin.

Comments.—Since the Steep Rock Lake series is almost identical in character with the Keewatin, the assumption of profound faulting and erosion to explain the absence of the former series west of Steep Rock Lake seems purely gratuitous, the natural explanation being that the two are the same, and that the discordance at the base of the Steep Rock series is marked in other localities by the occasional conglomerates described by Lawson and Smith at the base of the Keewatin. That unconformities are partly obliterated or difficult to discover when the discordant series are closely folded is well known, and that a break, if such exists at the base of the Keewatin, should be so strongly marked everywhere as at Steep Rock Lake could not be expected. A conglomerate in itself is of course no evidence of unconformity, but the conglomerates at the base of the Keewatin are of such a character that Dr. Lawson, who has studied the district, believes that they mark, if not a real unconformity, a profound change of physical conditions between the Contchiching and Keewatin. Also he holds that these conglomerates are sedimentary, rather than volcanic.

Fine and even lamination, it may be said, is not sufficient evidence that the rocks showing this structure are clastic. Such structures are found both in metamorphosed igneous and sedimentary rocks. Moreover, it cannot be assumed that such a structure corresponds with bedding, even if the rocks are clastic. Hence, until it is shown that the two do correspond, determinations of thickness based upon lamination can have little value.

Buell[1] describes and maps the Waterloo quartzite areas. These are a series of detached outcrops resting unconformably under the Lower Silurian

[1] Geology of the Waterloo Quartzite Area. By I. M. BUELL. Trans. Wis. Acad. Sci., Vol. IX., pp. 255–274.

of Southern Wisconsin. Within the quartzite are occasional layers of conglomerate. The different outcrops are apparently parts of a synclinal fold. As a result of the shearing much of the quartzite has been crushed, and sericite has developed.

Van Hise[1] considers the dynamic phenomena shown by the Baraboo quartzite ranges of Central Wisconsin. These rocks, indurated by cementation, exhibit all stages between massive quartzite showing microscopically little evidence of interior movement, through a rock having in turn fracture and cleavage, to one which is apparently a crystalline schist, but in thin section still giving evidence of its fragmental origin. The schistosity produced by the movement of the layers over one another is parallel to the bedding. In places *Reibungs* breccias have developed. At one point minor faulting was noticed. These phenomena are more marked in the North Range than in the South Range, and thus bear in favor of Irving's explanation of the structure as a part of a single great fold in a set of layers 12,000 feet thick, the North Range being on the leg of the fold, and thus requiring greater readjustment of the beds than those on the South Range, which are near the crown of the anticline.

Winslow,[2] in 1893, places in the Archean the granites, porphyries, and felsites of Missouri, and in the Algonkian the associated conglomerates, one of them bearing the Pilot Knob iron-ore.

Keyes,[3] in 1893, holds that the granites of Maryland are eruptive, since these rocks indiscriminately cut across the other igneous rocks of the region, as well as the gneiss; because they hold inclusions of the other rocks of the region; because the rocks cut show contact phenomena, and because a microscopical examination shows that they possess all the characters of rocks cooled from fusion.

Smyth,[4] in 1893, describes the rocks of Gouverneur, N. Y. The gneiss gives evidences of mechanical deformation in the shattering of the quartz and

[1] Some Dynamic Phenomena Shown by the Baraboo Quartzite Ranges of Central Wisconsin, by C. R. Van Hise. Journ. of Geol., Vol. I., No. 4, pp. 347–355.

[2] The Geology and Mineral Products of Missouri, by ARTHUR WINSLOW. From "Missouri at the World's Fair." (Official Publication of the World's Fair Commission of Missouri).

[3] Some Maryland Granites and Their Origin, by C. R. KEYES. Bull. Geol. Soc. of Am., Vol. IV., pp. 299-304.

[4] Petrography of the Gneisses of the Town of Gouverneur, N. Y., by C. H. SMYTH, Jr. Contributions from the Geol. Dept. of Columbia College. Reprinted from Transactions of the New York Academy of Sciences, Vol. XII., pp. 203–217.

feldspar particles. Within the feldspar, along the cracks, microperthite has developed which does not show any dynamic action. The granite is much later than the gneiss, but like it has to some extent suffered from dynamic action. In general it is massive, or nearly so, but there are zones of shearing where granulite and gneiss have developed. Also in one portion there is a dark rock approaching a diorite, into which the granite grades, but this is regarded as a basic segregation from the original magma. The crystalline limestone is rather uniform in its character, but where intruded by the granite, it is more coarsely crystalline, and various metamorphic minerals have developed. Near the base of the limestone is a pyroxenic rock, which is schistose, highly contorted, and is of somewhat doubtful origin, in the field being regarded as sedimentary, and under the microscope having an appearance which suggests an igneous origin. In this pyroxenic gneiss occasionally scapolite is found. The Potsdam is a pure vitreous quartzite, indurated by the process of cementation.

Nason,[1] in 1893, describes the gneissic rocks bearing iron-ore in the Adirondack region as precisely like the Mt. Hope type of rock, bearing the New Jersey magnetites, and it is thought that the two are probably contemporaneous, bedded deposits. These gneissic ores are non-titaniferous, and are to be discriminated from the titaniferous iron ores which are associated with the labradorite rocks or norites of the region. These in occurrence and association are wholly distinct from the ores belonging in the gneisses.

Lawson[2] describes the Santa Lucia granite of Carmelo Bay as resting unconformably below the sedimentary rocks (Miocene) of the Carmelo series. At the base of the latter is a fine basal conglomerate. Across the Bay of Monterey, in the Santa Cruz range, granite without doubt of the same geological range bears a similar relation to rocks which are of not later age than Cretaceous. The granite is therefore, at the latest, of pre-Cretaceous age.

C. R. VAN HISE.

[1] Notes on Some of the Iron-bearing Rocks of the Adirondack Mountains, by F. L. NASON. Am. Geol., Vol. XII., No. 1, 1893, pp. 25–31.

[2] The Geology of Carmelo Bay, by A. C. LAWSON. Bull. Dept. Geol., Univ. of Cal., Berkeley, Vol. I., pp. 1–59.

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